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RESEARCH ON GRASSLAND, FORAGE CROPS AND THE CONSERVATION OF VEGETATION IN THE UNITED STATES OF AMERICA

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ERRATUM :

The account of research at the South Carolina Agricultural Experiment Station unfortunately passed through all stages in the press out of its proper alphabetical order. The error was noted too late for possible correction.

INTRODUCTION AND SUMMARY

It may appear to be presumptuous for a non-American organization to attempt to present an account of the current position of research in some particular subject in the United States of America. The relevant information on research on forage crops, range management and the botanical aspects of soil conservation is, however, either not available in published form, or is scattered in a large number of official and other reports. This Bulletin has, therefore, been prepared in order, chiefly, to provide non-American readers with a reasonably detailed summary of the very extensive research projects, under Federal, State and other control, which are concerned with problems relating to the improvement of pastures and range lands, the production of forage crops, and the utilization of grasses and other vegetation in the conservation of soil in the United States.

The Bulletin deals first with the Division of Forage Crops and Diseases, one of the sections of the Bureau of Plant Industry in the U.S. Department of Agriculture. The work of this Division (pp. 9-18) is divided into five main projects, arranged on a crop basis, and dealing respectively with (1) alfalfa, (2) clover, (3) soybeans, (4) lespedeza, cowpeas and miscellaneous legumes, and (5) grass studies. Each of these crops is studied from the following aspects : (1) culture and production, (2) breeding and improvement, and (3) diseases. These investigations are conducted either in co-operation with other Federal agencies, or with State agricultural experiment stations, mostly under a formal memorandum of understanding, but in part informally.

An important recent development in the work of this Division has been the organization of the United States Regional Research Laboratory, State College, Pennsylvania, around which the pasture research in the twelve north-eastern State experiment stations is being centred (p. 16). The comprehensive scheme of research initiated there will make this Laboratory one of the leading centres throughout the world for the study of the problems of humid temperate pastures.

The range investigations of the Forest Service, U.S. Department of Agriculture are intended to supply basic information necessary for the intelligent utilization of forest and other range lands (pp. 19-27). They have for their object the perpetuation and improvement of the range, the revegetation of depleted areas, the safe-guarding of watersheds, the prevention of erosion, and the maximum forage and live stock production consistent with sound grazing practice and the social and economic welfare of the people and communities dependent upon range and forage land for grazing.

The field work of this Service is organized into six regional forests and range experiment stations, covering the western United States, and concentrated on experimental ranges, several of which are maintained by each station.

The research of the Soil Conservation Service, U.S. Department of Agriculture, deals with many aspects other than the use of grassland and forage crops as a protective cover for soil (pp. 28-41). As practically all aspects of this research are of direct or indirect interest to grassland and forage crop specialists in other parts of the world, we have included brief details of the terms of reference of the eight branches of the Division of Research in the SCS, whether these are directly within the scope of this Bureau or not.

This account contains new information not already published in our Bulletin 25, as there have been two distinct changes in the research organization of soil conservation. These are concerned with the transference to the SCS of those portions of the Divisions of Drainage and of Irrigation which related to investigations, experiments and demonstrations of construction and hydrologic phases of farm irrigation and land drainage, and also with the formulation of a new research programme consisting of a co-ordinated attack on problems of revegetation in the Great Plains.

Following this account of the scope of the Division of Research of the SCS, we give a brief summary of the work of the Section of Agronomy and Range Management, Division of Operations, SCS.

After a short reference to the studies in progress under the auspices of the U.S. Golf Association comes a long quotation from the report of the Division of Plant Biology, Carnegie Institution of Washington, giving details of the research of Dr. F. E. Clements and his associates on factor and function in adaptation, and on climax, succession and conservation.

The remainder of the Bulletin contains extracts from the most recent annual reports from practically all the agricultural experiment stations in the United States.

The accounts of the research in the Division of Forage Crops and Diseases, the Forest Service and the SCS were supplied to the Bureau by officers in those organizations. The extracts of experiment station reports were made in this Bureau, and have all been checked and approved by the Director or other responsible officer on the stations concerned.

The Bulletin is provided with indexes of subjects, genera and species being studied.

It will be noted that few names of American research workers have been included. This was done in view of the difficulty in obtaining the names of the individual research workers concerned with every research project mentioned in this publication. Any person interested in the names of staff of the various Divisions and Services of the U.S. Department of Agriculture or of the State experiment stations may refer to two publications.

(1) Directory of Organization and Field Activities of the Department of Agriculture. Misc. Publ. U.S.D.A. No. 304. February, 1938.

(2) Workers in Subjects Pertaining to Agriculture in Land-Grant Colleges and Experiment Stations 1938-39. Misc. Publ. U.S.D.A. No. 335. April, 1939.

Both are obtainable from the Superintendent of Documents, Washington, D.C. Price 20 and 25 cents respectively.

DIVISION OF FORAGE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, U.S. DEPARTMENT OF AGRICULTURE

The work of the Division of Forage Crops and Diseases of the United States Department of Agriculture is divided into five main projects on a crop basis as follows :

Alfalfa investigations ;
Clover investigations ;
Soybean investigations ;
Lespedeza, cowpeas and miscellaneous legume investigations ; and
Grass investigations.

Each of these main projects is further broken down into three work projects :

(1) Culture and production ;
(2) breeding and improvement ; and
(3) disease investigations.

Research under culture and production has to do mainly with such problems as the effect of various soil amendments, rate, date and method of seeding, cultivation, drainage, cutting and curing practices on the production of forage and seed. Studies on pasture management are also included. Breeding and improvement investigations include tests of varieties and strains from all parts of the world to determine their adaptation to environmental conditions, selection and breeding for resistance to cold and disease, and for greater productivity and better quality of forage and seed. Disease investigations are concerned with the study of the nature and effect of forage crop diseases, the life histories and host specialization of the parasites, and the control of losses therefrom by selection and breeding for resistance, by cultural practices and by other means. These investigations are conducted either in co-operation with other Federal agencies or with State agricultural experiment stations, mostly under a formal memorandum of understanding but in part informally.

Alfalfa Investigations

Fertilizer tests conducted for several years in various parts of the United States have demonstrated the need for lime and phosphorus on most soils in the eastern part of the United States. In addition, certain sandy soils require potash. In the West, where alfalfa has been grown for several years, a deficiency of phosphorus sometimes results, as demonstrated by the increased growth resulting from applications of this element. In a few localities, particularly in parts of Oregon, light applications of sulphur have proved very beneficial. Cutting experiments have shown that, in general, stands are maintained longer and yields are higher where cutting is delayed until the flowers have reached the full-bloom stage, though this is at the sacrifice of the feeding value of the hay. Cutting at the 1/10th to 1/2 bloom

stage results in fairly satisfactory yields of hay having a higher feeding value without a serious reduction in stand. Autumn cutting practices have been shown to have a direct effect on crown bud development, maintenance of stands and subsequent yields. In order to permit storage of ample food reserves in the roots, which has a direct effect on winter survival and yield the following year in the Northern States, the last cutting should be early enough to permit the growth of 10 to 12 inches before cold weather.

Co-operative studies with entomologists at Logan, Utah, showed that Lygus bugs (*Lygus hesperus* and *L. pratensis*) are a major factor in low seed yields in that general region. An infestation by these insects causes serious damage to buds and flowers which prevents them from setting seed pods. It appears that this damage is in part the result of some physiological disturbance in the plant brought about by attacks of these insects. Plants dusted five to seven times weekly with an insecticide produced four to six times as much seed as infested plants. In controlled studies at Manhattan, Kans., seed setting was favoured by relatively low soil moisture. Temperatures from 70 to 95°F. resulted in maximum seed production. Seed setting decreased rapidly at temperatures exceeding 100°F. but wide ranges in humidity appeared to have relatively little effect. In Nebraska honey bees were found to trip very few flowers, while leaf cutter bees tripped a high percentage of those visited.

Many varieties and strains of alfalfa from all parts of the world have been tested in plots in various parts of the United States. These tests have demonstrated that for the severe climatic conditions in the Northern States the alfalfas of the variegated group, including Grimm, Ladak, Hardigan, Baltic, and Cossack are most dependable. In the extreme South, where the winters are mild, some of the more rapid growing southern strains of common alfalfa are preferable. Under such conditions the cold resistant alfalfas are low in productivity. In the South-eastern States common alfalfa from Kansas and adjoining States has in general proved most satisfactory.

The breeding programme has been concentrated mainly upon selection and breeding for resistance to bacterial wilt (*Phytomonas insidiosa*), which is recognized as being the most serious disease of alfalfa in the United States. Where this disease occurs, it destroys in two to four years stands which formerly produced satisfactorily for 10 or more years. In a search for resistant strains, alfalfas from all parts of the world have been tested. Only those lots from Turkestan and an occasional lot from Persia, Afghanistan, and northern India have shown any considerable degree of resistance to the disease. Turkestan alfalfas are somewhat less productive than the better adapted domestic alfalfas, but, where bacterial wilt is a serious factor, are in general fairly satisfactory under the drier climatic conditions of the West. Under eastern humid conditions Turkestan alfalfas are generally unsatisfactory because of their susceptibility to leaf and stem diseases and to the potato leafhopper (*Empoasca fabae*) yellowing. Turkestan alfalfas have been used extensively in breeding for resistance to bacterial wilt by selection, selfing, and hybridizing with other alfalfas. Considerable progress has been made in developing strains highly resistant to bacterial wilt and apparently superior in other respects to alfalfas usually grown. Through plans developed by the Alfalfa Improvement Conference more than 100 new lines

resulting from the breeding programme have been tested in uniform nurseries in about forty States. The results obtained from these nurseries serve as a basis for eliminating the undesirable lines and for selecting the promising ones, which are increased for plot testing. The results from these larger trials will serve as a basis for commercial increase.

While bacterial wilt is recognized as being the most serious disease of alfalfa at the present time, other diseases are receiving consideration by pathologists, particularly the yellowing due to attacks of the potato leafhopper (*Empoasca fabae*) which is very prevalent in the eastern half of the United States resulting in a reduction in yields, and in carotin and protein content. Differences in yields and leafhopper infestation have been found to result from different cutting schedules, but no outstanding benefits have been obtained from any of the cutting schedules thus far compared.

Recently there has been an increased interest in alfalfas better suited for grazing. Several pasture type plants were selected from a cross between a so-called "creeping-rooted" or "re-rooting" introduction from Turkey, a characteristic which seems to be desirable in a pasture type, and a wilt-resistant selection. These segregates combine the creeping rooted habit with greater wilt resistance, greater vigour, and better seed production.

Clover Investigations

The studies conducted under this project relate to the genera *Trifolium* and *Melilotus*, of which there are approximately fifteen species of importance either extensively in many regions or intensively in restricted localities.

The need of phosphatic fertilizers for increasing the yields of red clover hay and seed in practically all regions where red clover is grown is evident. Relatively high applications of phosphatic fertilizers have more than doubled the seed yields of red clover when grown under irrigation. Preliminary studies in the Corn Belt States have indicated that the winter hardiness of red clover is increased by the applications of mineral elements to the soil.

Under dry-land conditions of the Great Plains, better stands of sweet clover, *M. alba*, have resulted from seedings made early in the spring in Sudan grass and wheat stubble than when made on fallow or on spring tilled land.

In the Middle-western and North-eastern States phosphatic manuring of white clover assists in stand establishment and increases growth.

In the South-eastern States early fall (autumn) seedings of crimson clover resulted in increased yields the following spring. The use of unhulled seed in the early seedings in many cases overcomes the hazards which cause stand losses, due to rapid germination with subsequent drying of the soil before the seedlings are established.

Louisiana white and Ladino clover were more productive than Kent wild white or a strain from one of the Corn Belt States. Under phosphatic manures without seeding, fair stands of native white clover developed in many places.

Studies with strawberry clover have indicated that stand establishment may be

facilitated by thorough seedbed preparation and with rates of seeding as high as 5 lb. per acre. In saline soils, strawberry clover is tolerant of saline concentrations from 3,500 to 4,000 p.p.m. and under favourable moisture conditions will thrive under concentration as high as 7,500 p.p.m.

In the South-eastern States the establishment and maintenance of stands of the winter annual species, *Trifolium resupinatum*, *T. procumbens*, *T. dubium*, *T. glomeratum*, *T. subterraneum*, and *T. repens*, which under these conditions behave mainly as winter annuals, have been markedly improved through the use of large applications of phosphatic fertilizers.

The objective of breeding work with red clover throughout the Corn Belt States is directed towards the elimination of the hazards affecting this crop and the development of desirable plant types. In the southern part of the eastern red clover belt, attacks of southern anthracnose caused by *Colletotrichum trifolii* are among the principal factors in red clover failures. By a combination of artificial inoculation, selection and natural top-crossing, resistance has been substantially increased. Mildew resistance in red clover has been obtained in several lines, but this resistance has been developed through inbreeding with a loss of vigour. Recombination of resistant lines to regain vigour and maintain resistance is in progress. Results of preliminary studies indicate that more than one genetic factor is involved in the inheritance of resistance to powdery mildew. A majority of 121 lines of red clover proved to be susceptible to northern anthracnose, *Kabatiella caulivora*, when artificially inoculated. Further selection and hybridization within and between resistant lines with artificial inoculation are being followed to increase the resistance. Using the natural resistance of Tennessee anthracnose-resistant red clover as an index, results show that when seed is removed from the infectious principle, red clover deteriorates perceptibly after three generations and materially after six generations. As a result of improvement studies, two red clover blends—one composed of four old selected strains adapted to the central section of the Corn Belt States, the other representing three selected strains adapted to the southern part of the red clover belt—are being increased in the North-western States under certification to supplement the production of home-grown adapted seed.

In sweet clover breeding, efforts are being directed towards the development of fine-stemmed types for hay and large-seeded strains for dry-land conditions, as well as of strains that are low in, or free from, coumarin and resistant to disease.

Strains of *M. alba* and *M. suaveolens* have been selected that appear more resistant to the black stem disease (*Ascochyta* spp.) and root rot (*Phytophthora megasperma*) than commercial seed. Selections of *M. alba* and *M. officinalis* low in coumarin have been obtained from different varieties.

Seed of alsike clover from different Canadian and domestic sources has not differed significantly in adaptation in the central part of the Corn Belt States. Results of red clover variety and source of seed experiments conducted in many places throughout the Eastern and Central States continue to show clearly that foreign varieties and strains are significantly inferior to adapted domestic varieties, even though losses from winter killing are negligible. Canadian has given results com-

parable to domestic seed in the northern section, but old adapted strains tested in the same latitudinal region where grown have proved superior.

Throughout the Corn Belt States, a disease complex of sweet clover is seriously affecting the profitable production of this crop. A root rot caused by *Phytophthora megasperma* appears to be increasing in prevalence. The increase of this disease appears to be related to length of time that sweet clover has been grown in the rotation on the same soil and to an excess of soil moisture during the spring months of the second year from seeding. Controlled studies have indicated that the organism will attack plants under soil temperatures ranging from 10° to 28°F. *Rhizoctonia* spp. and *Pythium* spp. have also been isolated from diseased roots. *Melilotus dentata* appears to be more susceptible to the disease complex than *M. alba*, *M. officinalis*, or *M. suaveolens*. Many fungi causing several serious diseases of sweet clover have been found to be seed-borne.

Along with other parasites affecting sweet clover, *Stagonospora meliloti*, *Phoma trifolii* and two fungi appearing to be species of *Fusarium* have been isolated from diseased plants with some frequency.

Controlled inoculation studies of red clover strains with southern anthracnose resulted in a loss of approximately 45 per cent of the plants of strains somewhat naturally resistant, while approximately 90 per cent of the plants of foreign and northern strains were killed. Studies on northern anthracnose, *Kabatiella caulivora*, indicate that there is a high correlation between favourable environmental conditions for growth and disease development.

Winter annual species of *Trifolium*, particularly *subterraneum* and *procumbens*, have been found to be susceptible to attacks of *Macrosporium* spp., *Rhizoctonia* spp., and *Sclerotinia* spp.

Soybean Investigations

Increased utilization of soybeans for hay, pasture, silage, and soil improvement, and in the manufacture of food and industrial products, has resulted in an increase in acreage during 30 years from about 50,000 acres to 8,000,000 acres. Production has increased from 3,000,000 bushels in 1929 from fourteen States to nearly 58,000,000 bushels in 1938 from twenty-five States.

During the past 30 years, the Department has obtained more than 10,000 introductions, representing over 2,000 distinct types, from China, Manchuria, Chosen, Japan, Java, Sumatra, India and Siberia. This collection, ranging in maturity from 75 to 200 or more days, has shown wide differences in adaptation to soil and climatic conditions, size, shape, colour, and composition of seed, and much variation in plant characters. Co-operative adaptation studies are being conducted at more than 150 stations in forty-six States, Alaska, Hawaii, and Puerto Rico. At present, about 5,000 individual plant selections from introductions and natural and controlled crosses are under test at Arlington Experiment Farm, Va. Chemical composition studies made in connexion with the breeding and adaptation studies show a wide range in percentage of oil, protein, calcium, phosphorus, potassium, and iodine number of varieties and selections grown under the same conditions, and also considerable variation in these constituents of the same variety grown under different

environmental and seasonal conditions. At present, 118 named varieties are handled by growers and seedsmen, or are under test by State experiment stations and the Department of Agriculture. These varieties may be classified according to use as follows : Grain or commercial purposes—55, forage—32, and for green or dry edible beans—31.

Breeding studies have been confined largely to selection of promising individual plants from introductions, natural hybrids, and some controlled crosses. With increased utilization of the soybean, a demand has arisen for development of varieties having characters especially suited for numerous food and industrial purposes. The improvement of varieties has thus become more complex, involving not only selection but also controlled crosses and more specific composition studies. Many selections having high oil, high protein, high oil and high protein, high seed yield, high iodine number, and low iodine number (indicating superior qualities for forage, food, and industrial purposes), are under field tests for comparison with standard varieties by different experiment stations and special co-operators. Several very promising types for green shelled beans, dry edible beans, roasted beans, and bean flour have been developed for various regions of the country and are being increased for distribution.

Although the soybean plant is attacked by a number of bacterial and fungous diseases, no one disease as yet has caused serious injury to the crop in the United States. Studies of the various diseases affecting soybeans indicate that varieties differ markedly in relative resistance to certain bacterial and fungous diseases. Many of the best edible types appear quite susceptible to mosaic and leaf-spot diseases. A few varieties appear immune, while in some of the susceptible varieties individual plants with varying degrees of resistance to the diseases have been noted.

The United States Regional Soybean Industrial Products Laboratory was established in the spring of 1936 as a co-operative activity between the twelve State agricultural experiment stations of the North Central Region and the United States Department of Agriculture. Direction of the chemical work to increase industrial utilization of soybean products was assigned to the Bureau of Chemistry and Soils, while direction of agronomic work and the development of improved varieties for industrial utilization was assigned to the Bureau of Plant Industry.

The agronomic programme includes four main projects, namely :—

(1) Effect of varietal, soil, and climatic factors on the composition of the soybean,

(2) Development by breeding and selection of improved varieties of soybeans for industrial utilization,

(3) Study of the effect of cultural and production methods on the yield, quality, and composition of soybean seed,

(4) Physiological research on the effect of environmental conditions on the growth and composition of soybeans.

Results obtained on commercial varieties over a period of 3 years indicate that variation in composition of many varieties grown on one soil type roughly equals variation in composition of samples of one variety grown on many soil types. Fer-

tilizer applications thus far have not materially affected the composition of the beans. In the breeding programme, all available introductions and selections with suitable maturity for any part of the region are being grown and studied as a source of superior parent material for crossing. Much progress has been made in developing superior strains for different regions and uses. Physiological research has included field studies in the correlation between available mineral constituents in the soil and composition of the soybean. Preliminary results under controlled conditions in the greenhouse indicate that variation in night temperatures has a marked effect on development of the seed. Progress has also been made towards producing more normal growth in the greenhouse under winter daylight conditions through studies of different types of artificial light and a sub-irrigation system of soybean culture.

Lespedeza, Cowpea, and Miscellaneous Legume Investigations

Lespedeza sericea continues to show great promise for a large area of low fertility soil where other legumes do but poorly. As a soil-improving crop it has given excellent results, and a large acreage is being used for this purpose. Being a long-lived perennial, it can be used to advantage where a permanent cover is needed. By reason of the low moisture content of the plants, *L. sericea* can be raked for hay soon after cutting and should be handled in this way for best results. This makes it an ideal crop for areas with uncertain weather. A study of the factors influencing the tannin content of *L. sericea*, which is its one serious fault, is being undertaken in co-operation with the Bureau of Chemistry and Soils and it is hoped that this will give information that will be helpful in developing superior varieties for forage.

Fertilizers, especially superphosphate, are necessary for best results in growing winter cover crops in the South, and early fall (autumn) planting is essential in order to obtain a good growth to be turned under in late winter for green manure. Experiments in methods of utilizing summer cover crops continue to show the value of allowing such crops to stand in the fall rather than to be worked into the soil when not followed by a winter growing crop.

Crotalaria seeded with small grains and allowed to volunteer has given increased yields of grain with little additional expense. Fertilizers have not increased yields of *Crotalaria*, indicating the value of this crop for use on soils of low fertility. Early-maturing strains of *Crotalaria intermedia* have been selected.

The use of annual lespedezas for hay and pastures has steadily increased. Applications of superphosphate are needed for best growth. The cause of a wilt disease, which affects particularly the Early Korean strain, has been shown to be a previously undescribed species of bacterium and the name *Phytomonas lespedezae* has been proposed for it.

A variety of common vetch, F.C. 34947, which promises to be of superior value for cover crop use in parts of the Cotton Belt, was for the first time grown in commercial plantings.

Kudzu (*Pueraria thunbergiana*) is proving adapted to a wide range of conditions; besides being a valuable forage crop, it is excellent for erosion control.

A study of field pea (*Pisum* sp.) diseases undertaken in co-operation with the

Georgia Agricultural Experiment Station showed that several serious diseases are involved and that rotation is a likely means of control. In experimental plots and in field plantings, it was observed that disease is least severe where field peas are grown on land not recently planted to this crop and is most severe where the crop has been grown continuously for a number of years.

Grass Investigations

The season of 1938 was the third season of extensive grass improvement work conducted in co-operation with State and Federal Experiment Stations in the major agricultural regions of the United States. Numerous native and introduced species assembled in nurseries afforded abundant material for determining the range of variability within the species, those species of greatest promise within given regions, and the types of these species suitable for hay and pasture use. In the beginning the work was largely exploratory, but since 1937 research has tended to become more concentrated with respect to those species in each region which are most likely to become the basis of grass improvement activities.

Pasture Regions of the United States, according to P. V. Cardon (Report of Fourth International Grassland Congress, 1937).

In the North-eastern region, grass research has centred around the United States Regional Pasture Research Laboratory in co-operation with the twelve North-eastern State Experiment Stations (see *Herb. Rev.* 6. 146-50. 1938). Cytogenetic and environmental studies have been made in the field and greenhouse with individual grass plants grown from seed and cuttings. The grasses studied include : *Agrostis* spp., orchard grass (*Dactylis glomerata*), *Festuca* spp., perennial ryegrass (*Lolium*

[To face p. 16

U.S. Regional Pasture Research Laboratory.

From the full account of the Research at this Laboratory by its Director, Dr. R. J. Garber, in *Herbage Reviews*, 6. No. 3. 1938.

perenne), timothy (*Phleum pratense*), Canada bluegrass (*Poa compressa*), and Kentucky bluegrass (*Poa pratensis*). Clonal material from the sod plugs taken in pastures in several North-eastern States has shown a wide range in variation. Preliminary studies indicate that artificial light to supplement daylight is immediately effective in inducing flower stalks in Canada bluegrass, but not in Kentucky bluegrass.

In the South-eastern region at Tifton, Georgia, *Digitaria* spp. and *Phalaris tuberosa* have appeared most promising of the large number of species tested. Several interesting new types have been found in Napier grass (*Pennisetum purpureum*). No evidence of resistance to ergot (*Claviceps paspali*) has been found in Dallis grass (*Paspalum dilatatum*), but one lot of *Paspalum malacophyllum* proved highly resistant to the disease. Turning and stirring the soil once in three years have been found necessary to maintain a good Bermuda grass (*Cynodon dactylon*) pasture in the Coastal Plains. Phosphatic fertilizers appear necessary on lowland pastures in which white clover is included. Fertilizer applications on uplands have increased the gain of beef cattle, but the economy of such treatments is still to be determined. At Gainesville, Florida, several selections of *Pennisetum purpureum* have proved resistant to eye-spot (*Helminthosporium ocellum*). The most desirable types are being selected for silage and pasture use.

In greenhouse compartments where temperatures could be controlled at Columbia, Missouri, the optimum temperature for herbage production was between 80°F. and 90°F. for Kentucky and Canada bluegrass, and 70°F. for orchard grass. All three were severely injured by continuous air and soil temperatures at 100°F. Herbage production for Bermuda grass was greater at 100°F. than at any lower temperature. In Kentucky and Canada bluegrass and orchard grass, the percentage content of nitrogen-free extract declined with rising temperature, but increased in Bermuda grass. In all four grasses the crude fibre content increased as the temperature rose from 40°F. to 60°F. and changed very little with further rises in temperature. The percentage of crude protein declined slightly in Kentucky and Canada bluegrass and orchard grass as the temperature increased from 40°F. to 60°F. and then increased slightly as the temperature rose above optimum for growth. In Bermuda grass the crude protein content was much greater at 50°F. than at 60°F.

Grazing results at Grain Valley, Missouri, emphasized the importance of maintaining a pasture of Korean lespedeza to supplement Kentucky bluegrass in midsummer. Thirty head of steers were pastured on two acres of Korean lespedeza for 8 weeks. At the end of the grazing period the cattle on Korean lespedeza pasture were one grade higher than those continued on bluegrass during the period, and produced 38 per cent greater live weight gain.

At Madison, Wisconsin, superior strains of *Poa pratensis*, *P. compressa* and *Bromus inermis* were found among collections made in Wisconsin and in adjoining States.

Cytological studies of apomictic seed development in *Poa pratensis* have revealed details of this phenomenon not observed by previous investigators.

At Mandan, North Dakota, many grasses adapted to cold, dry regions, including crested wheatgrass (*Agropyron cristatum*) and western wheatgrass (*Agropyron smithii*) are being studied critically. Considerable progress has been made in selecting im-

proved strains. Under these conditions, southern strains of buffalo grass (*Buchloë dactyloides*) make more rapid growth than northern strains.

At Lincoln, Nebraska, promising selections have been made from *Bromus inermis*, *Andropogon furcatus*, *Bouteloua curtipendula*, *Buchloë dactyloides*, *Agropyron cristatum*, *A. smithii*, *Panicum virgatum* and *Poa pratensis*.

At Manhattan, Kansas, superior strains of *Andropogon furcatus* and *A. scoparius* have been selected.

At Cheyenne, Wyoming, treatments involving various day lengths and night temperatures indicate that the top growth of all species studied was favoured by long days and warm temperatures. High light intensity plays an important part in flowering, seed setting, and chorophyll development of western grasses such as blue grama, western wheatgrass, and brome grass. The outstanding native species for Wyoming conditions are *Agropyron smithii*, *Bouteloua gracilis*, *Elymus canadensis*, and *Buchloë dactyloides*.

In the Southern Great Plains at Woodward, Oklahoma, and at various places in the "Dust Bowl" an intensive study of grass cultural and production problems of native and introduced species is under way. Methods of establishing pasture and range grasses showed that the stubble of a preceding crop of Sudan grass or sorghum is ideal for controlling soil blowing prior to grass establishment. Grass stands in pastures have been improved by broadcasting the cured hay of native grasses containing mature seed.

At Bozeman, Montana, high seed yields of *Agropyron cristatum* and *Bromus marginatus* were obtained under irrigation. Iarovization (vernalization) and day length tests failed to cause *Agropyron cristatum* or *Bromus inermis* to fruit in one winter.

At Pullman, Washington, many improved selections have been made from adapted native species. Intergeneric hybrids of wheat, rye, barley, and oats with numerous grass species have been made. Many grasses have been studied for resistance or susceptibility to diseases, particularly the smuts. Investigations are being made of the general biology, life history, and host specialization of the following grass smut fungi: *Ustilago bullata*, *U. perennans*, *U. hypodytes*, and *U. striaeformis*.

At Corvallis, Oregon, genera exhibiting combined winter hardiness, long season growth, and fair to good seed production include *Festuca*, *Arrhenatherum*, *Dactylis*, *Bromus*, *Brachypodium*, *Poa*, *Phalaris*, *Arundinaria*, and *Lolium*.

At Logan, Utah, seed of several species of grass collected at different stages showed high germination for most lots collected in the milk stage. Seed collected before the milk stage gave lower germination and produced inferior seed. The results indicate that the species studied may be harvested safely before maturity and thus loss from shattering is avoided.

RANGE RESEARCH OF THE FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Range investigations of the Forest Service, United States Department of Agriculture, are for the purpose of supplying basic information needed for the intelligent handling of forest and other range lands. They have for their object the perpetuation and improvement of the range, the revegetation of depleted areas, the safeguarding of watersheds, the prevention of erosion, and the maximum forage and livestock production consistent with sound grazing practice and the social and economic welfare of the people and communities dependent on range and forest land for grazing.

The field work is organized into six regional forests and range experiment stations covering the western United States and concentrated on experimental ranges, several of which are maintained by each station. The research is concerned primarily with four broad phases:

Range management investigations;
Artificial revegetation investigations;
Range forage investigations; and
Watershed protection.

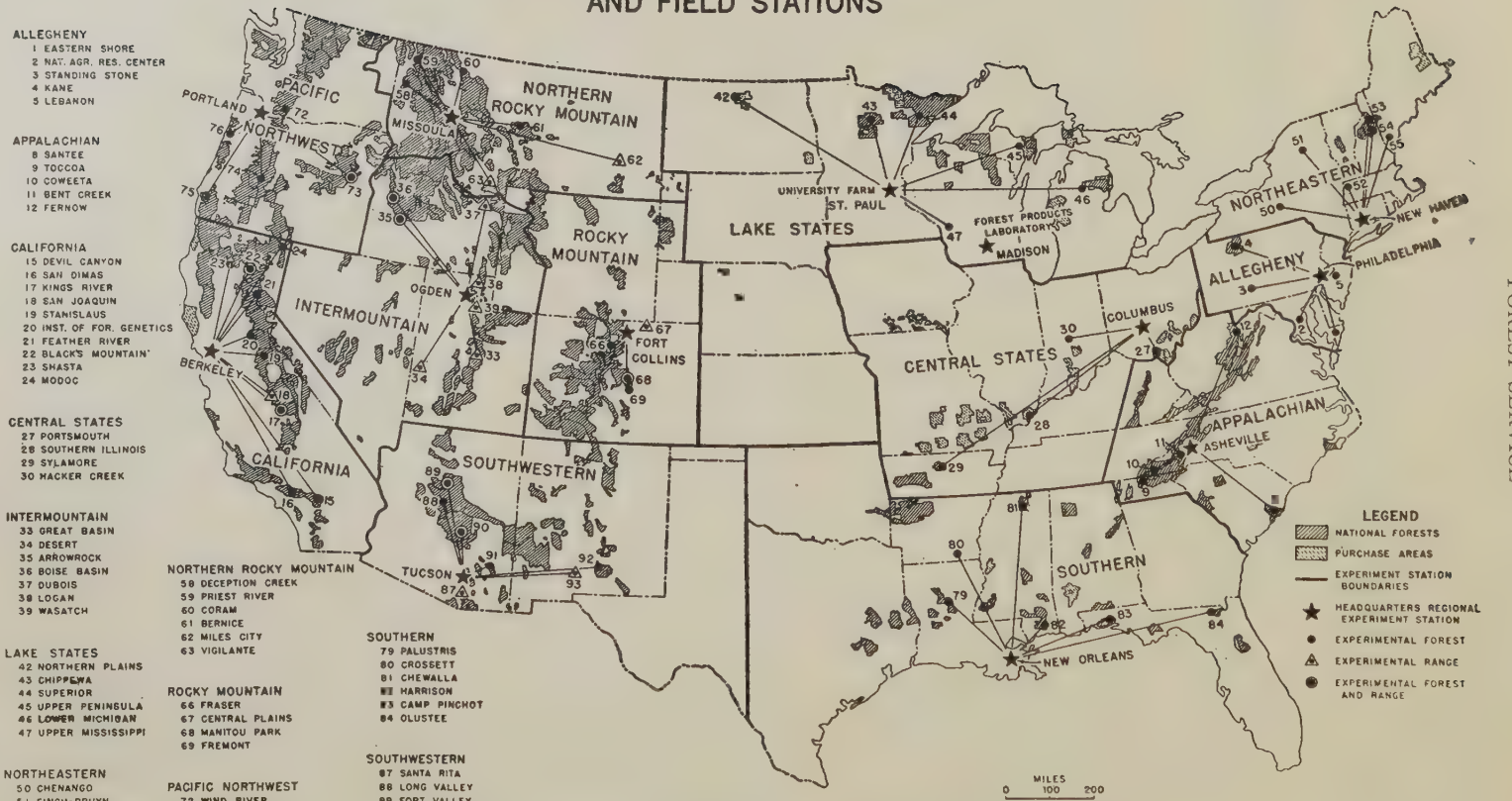
Grazing management research aims at developing methods of grazing, consistent with the conservation and use of other resources of the land, that will under the fullest possible use restore and maintain the forage and produce livestock most effectively and economically. Studies now being conducted include climate and plant growth relationships, forage production, standards of satisfactory forage utilization, noxious plant control, seasons of grazing use, grazing capacity, and system of management including the recognition and correlation of timber production and other land services in relation to grazing. These studies are located on representative areas in the Great Plains, semi-desert mesas, valleys, and foothills of the south-west and California, and mountainous areas of the West.

The principal objective of research in artificial revegetation is to develop methods and suitable species for seeding or transplanting on range lands now so badly depleted that reasonably rapid natural revegetation appears improbable. Studies are in progress to develop methods of restoring artificially the plant cover on seriously depleted ranges and abandoned dry farms in the West.

Range forage investigations involve the collection, analyses, and dissemination of information on the identity, distribution, grazing requirements, life histories, forage and watershed protective and other values of range plants.

Watershed protection research on range lands seeks to determine the fundamental principles of how vegetation cover controls erosion and stream flow and the extent to which the cover can be modified for beneficial use of the forage without damaging watershed values. It includes studies of: (1) the relation of different types and conditions of vegetation to soil, run-off, percolation, use of moisture by

FOREST SERVICE RESEARCH CENTERS AND FIELD STATIONS



ALLEGHENY
1 EASTERN SHORE
2 NAT. AGR. RES. CENTER
3 STANDING STONE
4 KANE
5 LEBANON

APPALACHIAN
8 SANTEE
9 TOCCOA
10 COWEETA
11 BENT CREEK
12 FERNOW

CALIFORNIA
15 DEVIL CANYON
16 SAN DIMAS
17 KINGS RIVER
18 SAN JOAQUIN
19 STANISLAUS
20 INST. OF FOR. GENETICS
21 FEATHER RIVER
22 BLACK'S MOUNTAIN
23 SHASTA
24 MODOC

CENTRAL STATES
27 PORTSMOUTH
28 SOUTHERN ILLINOIS
29 SYLAMORE
30 WACKER CREEK

INTERMOUNTAIN
33 GREAT BASIN
34 DESERT
35 ARROWROCK
36 BOISE BASIN
37 DUBOIS
38 LOGAN
39 WASATCH

LAKE STATES
42 NORTHERN PLAINS
43 CHIPPEWA
44 SUPERIOR
45 UPPER PENINSULA
46 LOWER MICHIGAN
47 UPPER MISSISSIPPI

NORTHEASTERN
50 CHENANGO
51 FINCH-PRUYN
52 HOPKINS MEMORIAL
53 GALE RIVER
54 BARTLETT
55 MASSABESIC

NORTHERN ROCKY MOUNTAIN
58 DECEPTION CREEK
59 PRIEST RIVER
60 CORAM
61 BERNICE
62 MILES CITY
63 VIGILANTE

ROCKY MOUNTAIN
66 FRASER
67 CENTRAL PLAINS
68 MANITOU PARK
69 FREMONT

PACIFIC NORTHWEST
72 WIND RIVER
73 BLUE MOUNTAIN
74 PRINGLE FALLS
75 PORT ORFORD CEDAR
76 CASCADE HEAD

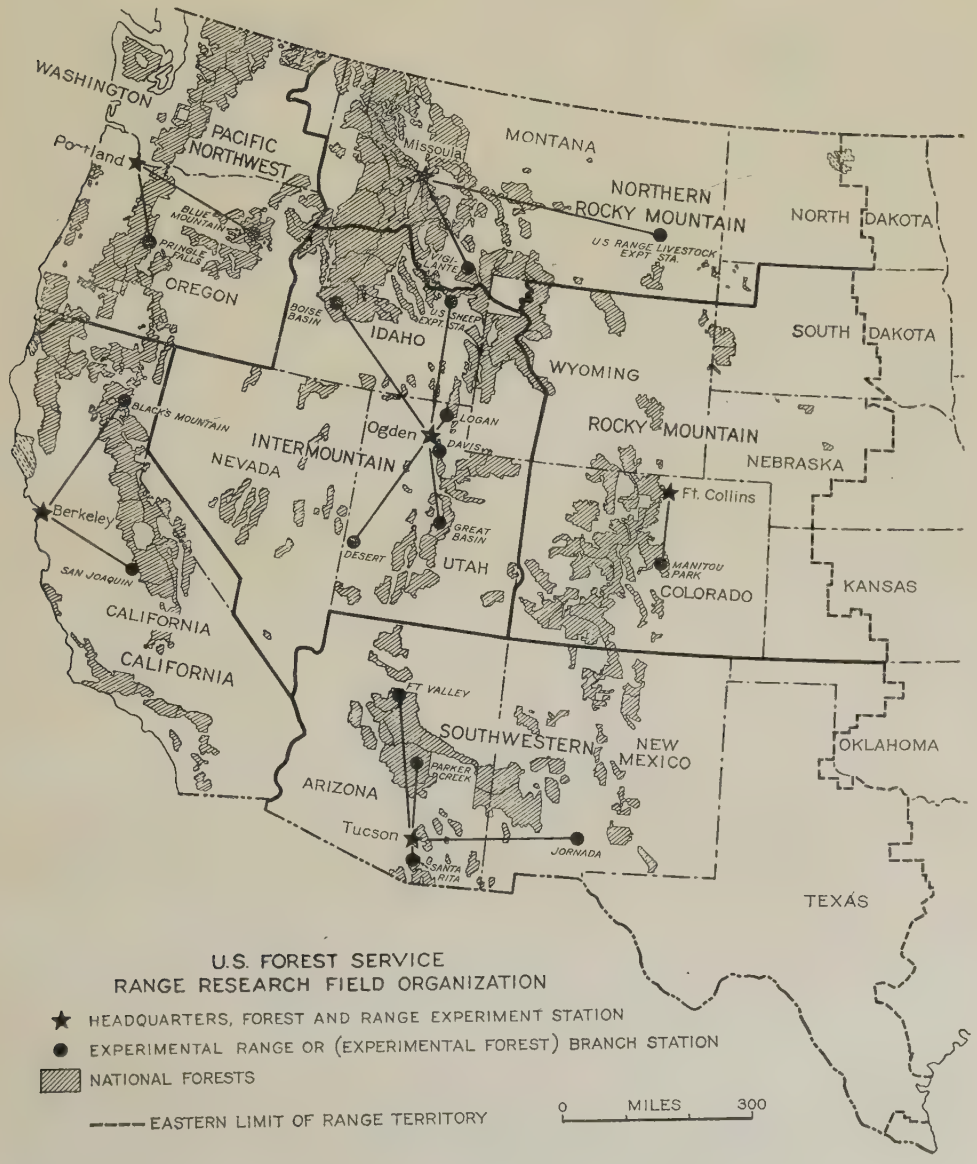
SOUTHERN
79 PALUSTRIS
80 CROSSETT
81 CHEWALLA
82 HARRISON
83 CAMP PINCHOT
84 OLUSTEE

SOUTHWESTERN
87 SANTA RITA
88 LONG VALLEY
89 FORT VALLEY
90 PARKER CREEK
91 MT. GRAHAM
92 CLOUDCROFT
93 JORNADA

Map by courtesy of Forest Service, U.S. Department of Agriculture.

vegetation, and delivery of usable water for irrigation, power and domestic use; (2) erosion control primarily through vegetation; and (3) the cost of control work that can be justified on range lands on an economic basis.

Various phases of the above investigations are conducted in co-operation with other Federal agencies and/or with the seventeen Western State Agricultural Experiment Stations.



Range Management Investigations

Numerous grazing practices now widely applied on national forest ranges have been developed by early empirical range management studies. These include: (1) deferred and rotation grazing which permits full use of the forage but delays grazing until after seed dissemination on a different portion of the range each year; (2) later opening dates for ranges more in harmony with readiness of plants for grazing; (3) a fairly good basis for determining the approximate grazing capacities of mountain range types; (4) improved methods for grazing sheep and goats, such as open and quiet herding, and bedding them down in a new place every night to avoid damaging the range through trampling and localized over-grazing; (5) obtaining better distribution of cattle on the range through well-placed watering places and better salting methods, thus bringing about more even and more effective use of the available range forage; (6) the eradication of tall larkspur; and (7) the development of the system of range surveys. These improved practices, often modified by empirical studies to meet local conditions and supplemented by more recent findings, have brought millions of dollars of savings and increased revenues to the livestock industry, and have been a big factor in the considerably better conditions now found on national forests as compared with the average of other range ownerships.

Early studies of grazing in relation to timber production in Arizona, Idaho and Utah brought out the possibilities of damage to timber reproduction from too heavy or unseasonable grazing and indicated major adjustments required. More recent investigations by the South-western Station of the relationships between frequency of watering livestock and damage to young growth of ponderosa pine are making possible the use of the range without undue injury to timber reproduction. It was found that, irrespective of whether or not the range forage was depleted, cattle watered only once in three days drank only one-third as much as where water was available at all times, and did far greater damage to reproduction; evidently they satisfied their thirst by browsing the succulent new pine shoots.

Twenty years' results on South-western semi-desert ranges, with regard to range management in relation to the severe periodic droughts, have attracted much attention. Conditions on these experimental ranges show marked contrasts with those on heavily stocked unregulated range of potentially equal productivity; for instance, the grazing capacity on the managed range is double that of the unregulated, net calf production is more than half again larger, and death losses are only one-fifth to one-third. A profit of 8.8 per cent has been earned on an investment of $69.23 per cow over a period of 11 years in an experimental herd on the Santa Rita Experimental Range. To maintain profitable production on these ranges where forage production may vary several hundred per cent between good and bad years, assurance of adequate range feed in most years is essential. This necessitates stocking about 20 to 25 per cent below average grazing capacity and requires other adjustments in the driest years, as well as delayed re-stocking. These investigations, now confirmed by studies in other parts of the western United States, show that the density of vegetation reflects the growth conditions of the previous year. Thus, the stand of forage plants

may be only one-fourth as much in the year following drought as in the year of drought.

Studies of grazing capacity in the short grass type of the northern Great Plains indicate that as little as 25 per cent overgrazing in the average year gave lower calf crops, smaller calves at birth, and an average of 72 lb. less weight at weaning than from cows on conservatively grazed range. Feed costs were half as great again on the overgrazed range. In the mountains of Utah, stocking approximately 20 per cent below average forage production has been found the wisest management practice. Safe utilization on spring and autumn ranges in southern Idaho, characterized by sagebrush—bunchgrass vegetation, is 65 per cent of the average forage production.

With regard to furnishing more satisfactory and uniform range forage utilization standards and methods of applying them on national forests and other ranges, some important findings have been obtained. For example, proper grazing use of black grama (*Bouteloua eriopoda*) is about 50 per cent of the total growth of the plant on a weight basis by the end of the grazing season, which usually means that from 70 to 85 per cent of the height growth is taken on most plants. On ranges in fair to good condition the grazed stubble should be cropped not closer than two or three inches above the ground by the end of the grazing season in June, under both year-long and seasonal winter use. In addition, one-fifth of the flower stalks and most of the runners should be ungrazed. On badly run-down black grama ranges, black grama should be grazed somewhat less to restore the plant to dominance. Under such conditions only 35 per cent of the grass should be taken by the end of the season instead of 50 per cent. This would leave one-third of the flower stalks and most of the runners untouched, and grazed portions cropped not closer than three or four inches above the ground.

Climate is a primary factor in range plant growth. Soil texture, structure, and fertility also play an important part in forage production, the rate of improvement of the native forage stand, and the ability to reseed areas artificially. Non-eroded range soil is much richer than eroded soil in lime, phosphoric acid, and total nitrogen; the water-holding capacity is greater; and the water required by representative plants to produce a pound of dry matter is less. A great many more leaves, greater stem and leaf length, and more dry matter are produced on the non-eroded than on the eroded soil, even with a notably smaller supply of water. Studies in several parts of the West have shown that, with each stage of depletion of the range vegetation, the situation on a range area becomes more critical as regards both production of forage and restoration of the plant cover. The intensification in the microclimate is reflected in such features as higher temperatures, more rapid run-off, less absorption of moisture by the soil, greater evaporation, increased requirement of water for the production of an equal quantity of forage and more damage from prolonged dry spells.

In studies of the relation of plant succession to range management, various stages have been traced through which vegetation must proceed in order to restore depleted range to a suitable cover. The trend is normally from annuals through

certain weed stages to perennial grasses. This trend is more marked on alpine range lands of central Utah than on the sandy and clay soil areas of semi-desert ranges of southern New Mexico.

Recent physiological studies have shown the close relationship of carbohydrate production and storage to range plant growth. Yield of forage is in direct relation to carbohydrate production during the current summer, and carbohydrates stored in the roots in the autumn determine the start of active growth the following year and relative vigour of the plants. These studies have shown how too frequent or heavy grazing at any time literally starves the plants to death, and thus conservative grazing is essential to permit perennial range grasses to manufacture and store sufficient carbohydrates.

Artificial Revegetation Investigations

Approximately 600 tests throughout the West have indicated that there is little chance for improving the bulk of native range lands in their present condition by the introduction of the common cultivated forage plants. Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*) and smooth brome (*Bromus inermis*) have been successful in about 100 tests where soil and moisture conditions are especially favourable, such as dry mountain meadow areas on which the vegetation has been depleted but from which the surface soil has not been removed by erosion. On moist mountain meadows, especially in the Pacific North-west, redtop (*Agrostis alba*) and alsike clover (*Trifolium hybridum*) have proved best. Success was attained only where a very thin stand of native vegetation occurred.

Slender wheat grass (*Agropyron pauciflorum*) and mountain brome (*Bromus carinatus*) have shown unusual promise on depleted mountain ranges in Central Utah. Both of these seed readily, produce abundantly, withstand moderately close grazing, and have increased the forage value of experimentally seeded areas six to ten times. Smooth brome increased the grazing capacity six times when seeded on oak-brush range with an average of 17 inches of rainfall. Crested wheat grass (*Agropyron cristatum*) under those conditions gave somewhat smaller increases. Fall (autumn) seeding proved most reliable.

Extensive experimental transplantings of native grasses, especially several species of grama (*Bouteloua*), made on mountain and mesa ranges in the South-west where rainfall averages only 9 inches annually, have resulted in a 50 per cent survival of transplants of black grama (*Bouteloua eriopoda*), mesa dropseed (*Sporobolus flexuosus*), paspalum (*Paspalum stramineum*), and 4-winged saltbush or "chamiza" (*Atriplex canescens*).

Crested wheat grass has proved to be the best species adapted to the drier conditions on abandoned cultivated fields of dry farms in Montana which should be restored to range. Somewhat deeper seeding than one-half inch has proved more successful. Smooth brome, slender wheat grass, meadow fescue (*Festuca elatior*), Canada bluegrass (*Poa compressa*), tall oatgrass (*Arrhenatherum elatius*) and Harbin lespedeza (*Lespedeza stipulacea* form), have also given fair results.

Of importance in artificial revegetation research is the development of methods sufficiently low in cost to be economically feasible on a large scale under the dry range

conditions generally prevailing. In the sagebrush type of the Intermountain mountain slopes, contour furrowing at about three feet intervals, and covering the seed with a brush drag will form a satisfactory stand without the necessity of ploughing the entire area. Recently a horse drawn hand drill with outrigger wheels has been developed which makes it possible to seed effectively steep slopes up to 72 degrees. This instrument has been used with success in reseeding portions of the steep mountainous area within the Boise watershed in the West.

A station has recently been established in co-operation with the Bureau of Plant Industry and the Utah State Agricultural College at Logan, Utah, to study the selection and breeding of plants suitable for forage and watershed protection on range lands and the introduction of foreign or native plants.

Range Forage Investigations

Nearly every approach to range management and improvement is intimately concerned with a knowledge of the range plants, their identification, growth requirements, life history, other ecological relationships, and forage and other values. Work of this character is organized in a Section of Range Forage Investigations in the Division of Range Research, Washington, D.C. It draws upon collections of, and information about, range plants by all members of the Forest Service throughout the United States, co-operates with the Bureau of Plant Industry and the U. S. National Museum in identification and classification, maintains a range plant herbarium, and assembles, analyses, interprets and disseminates information on range plants. These collections, many of which are made in inaccessible and poorly botanized areas, have made important contributions to western American plant taxonomy with regard to knowledge of distribution of and variations in species, resulting in some cases in the reduction of hitherto accepted species to synonymy, as well as in the discovery of valid new species hitherto unknown.

The range plant herbarium of the Washington office now consists of approximately 80,000 specially annotated specimens, representing about 1,400 genera and 8,000 species and varieties, collected by about 1,200 Forest Service officers. This herbarium is not only the fullest collection of western American montane plants extant, but also unique in the wealth of ecological, phenological, and economic data which accompany these specimens and thus facilitate correlation of data from different parts of the country.

Early information regarding the life history, forage values, and grazing requirements of several key forage grasses and other herbaceous plants on national forest ranges was summarized for the use of range administrators in developing better grazing management practices on the national forests. The economic importance, forage value and indications of proper grazing use of important western browse plants which furnish a major part of the feed for livestock on many ranges are also available. Recently, important information has been published regarding grazing, watershed protective cover, recreational and other uses of 339 important range plants in succinct, understandable, complete and readily usable form for stockmen, range administrators and other interested parties.

Watershed Protection

On many forest areas in the West where the tree cover is not sufficiently dense to serve alone in watershed conservation, the herbaceous and other understorey vegetation is the principal erosion-control agent. This is true also on the 575 million acres of untimbered range land. The management of grazing on these lands must, therefore, take watershed values into account.

Serious depletion of the herbaceous and shrubby vegetation, the result of past or present overgrazing, still prevails on enormous areas, especially in the semi-arid regions. Forest Service surveys of the Colorado River watershed above the Arizona-Utah line and the Rio Grande watershed above the Elephant Butte dam in New Mexico show that approximately 75 per cent of these watersheds is eroding more or less severely, largely because of overgrazing.

It has been found that restoring the cover on subalpine range lands in central Utah from an annual weed type, which covered about 16 per cent of the soil surface, to perennial vegetation covering about 40 per cent, reduces both surface run-off from summer rains and erosion by about 50 to 60 per cent.

Depletion of the plant cover increases run-off and erosion, and reduces absorption of moisture by the soil. This is illustrated by the results on granitic soils on the Boise River Watershed. Using a portable rain-making apparatus and storms of 2-inch per hour intensity, tests have now been made of the relative value of several herbaceous cover types or stages of range deterioration. In the bunchgrass type, supporting an average cover density of about 35 per cent, only 0.4 per cent of the rainfall ran off the surface and six lb. of silt were eroded per acre. The loose porous soil, interpenetrated with the fibrous root systems of the bunchgrass, absorbed practically the entire precipitation. The needlegrass-lupine type or stage, with a cover density of 30 per cent, permitted over 45 per cent of the rain to run off and about 5,000 lb. of sediment to be removed per acre. The annual weed type which is an extreme stage of depletion allowed a run-off of 60 per cent of the rain which carried with it 15,000 lb. of eroded material per acre. The downy chess, or cheat-grass type, also an advanced stage of deterioration, but with a cover density of 25 per cent, serves rather well except for cloudbursts, when serious run-off and erosion occur.

Also on the Boise River Watershed a survey of the conditions influencing erosion showed that gradient, soil, plant type, density of vegetation, rodents, and degree of use by livestock are all important erosion causes. Under the conditions of the study a vegetation cover of less than 30 per cent appears to have little appreciable effect in retarding erosion. A cover of 40 per cent, however, is sufficient to prevent gully erosion under normal grazing use. Erosion increases with gradient only up to 35 per cent since on the steeper slopes lighter grazing and other factors tend to offset the gradient factor.

A terrace-trench system of flood control has been developed in northern Utah where floods originating on very small critical overgrazed headwater areas had caused $1,000,000 damage. The terraces have not only held torrential rains in 1936 which caused floods from untreated adjacent watersheds, but have made possible artificial reseeding of the steep eroded slopes with native grasses. Although the cost has

averaged about $24 per acre treated, the damage in the valley from the floods which originated on these lands amounted to nearly $1,200 per treated acre.

Destruction of the vegetative cover on the Salt River watershed has been suggested to give greater run-off under the semi-desert conditions prevailing there. This does not take into consideration the fundamentals underlying water delivery, water used by vegetation, and the silting that is impairing the reservoirs. The bulk of the water for irrigation comes from underground supplies of percolated precipitation, chiefly melted snows in the timbered higher mountains. Most of the erosion comes from summer rains falling on depleted ranges at lower elevations.

Transpiration and evaporation plots supporting shrubs and grasses on these range lands lost, chiefly during the summer growing season, only one-tenth to three-tenths more moisture than bare soil, owing to the limited rainfall. In winter, most of the precipitation percolates to underground supplies. At that time transpiration is no greater than the light evaporation from bare soil. The benefit of the plant cover in checking soil erosion outweighs many times the value of the slight amount of precipitation used by the plant cover.

Economic Considerations

The only way to measure the value of research and also of the range resource itself is in terms of social and economic welfare. Range information is sparse and there are so many pressing problems of vital economic importance that practically all research undertaken with regard to range lands must have a return of practical value in sight.

Reference has already been made to the increased savings and production returns from application of research principles on national forests, the profitable returns from improved range management on the Santa Rita Experimental Range, and the economic justification for the terrace-trench system of flood control in Utah. Similar determinations of the practical economic values of improved practices are made for most of the other principles developed by the research. For example, the studies of grazing capacity in the short-grass plains at the U. S. Range Livestock Experimental Station in eastern Montana, in co-operation with the Bureau of Animal Industry and the Montana State Agricultural Experiment Station, show that conservative grazing pays in contrast to stocking at only about 25 per cent in excess of grazing capacity. Calf crops are one-sixth greater, one-third more lb. of calves are produced per cow, and feed costs per lb. of calf produced are considerably less under conservative grazing.

It is just as important to know what plants should not be used in artificial reseeding and the conditions where reseeding is apt to fail as it is to know which may prove successful. Thousands of dollars have been wasted by stockmen in unsound efforts at artificial reseeding.

In connexion with national forest administration, studies are being made of the value of national forests to local communities, of what fees should be charged for grazing privileges, and of how the use of dependent private ranch lands can best be co-ordinated with grazing use of national forests.

DIVISION OF RESEARCH, SOIL CONSERVATION SERVICE

U.S. DEPARTMENT OF AGRICULTURE

The work of the Soil Conservation Service, U.S. Department of Agriculture, is organized under four divisions, namely :—

Division of Conservation Operations.
Division of Co-operative Relations and Information.
Division of Research.
Division of Watershed and Conservation Surveys.

The scope of these four Divisions is briefly outlined in Bulletin 25 from this Bureau, pp. 126-9. In that publication it was noted that the Division of Research was sub-divided into six sections dealing with the following aspects :—

(1) Soil and water conservation experiment stations.
(2) Watershed studies.
(3) Sedimentation studies.
(4) Climatic and physiographic investigations.
(5) Hill culture.
(6) Economics of soil conservation.

Since the period covered in Bulletin 25 there have been two distinct changes in the research organization of soil conservation. The first of these was effective as from January 1, 1939. This consisted of the transference to the Soil Conservation Service of those portions of the work of the Divisions of Drainage and of Irrigation which relate to investigations, experiments and demonstrations of construction and hydrologic phases of farm irrigation and land drainage. At the same time those portions of the work of these two Divisions which relate to investigations, experiments and demonstrations in connexion with crop production and irrigable lands, quantity of irrigation water and its use by crops, and measures for improving and maintaining productivity of irrigated soils were assigned to the Bureau of Plant Industry.

The second research development in the process of formulation consists of a co-ordinated attack upon problems of revegetation in the Great Plains. Special interest is centred upon methods which can be used to retire eroded land back to grass, in order to obtain a productive vegetative cover. The exact methods to be followed are not yet determined, as it is very difficult under conditions of highly variable rainfall to establish grasses upon the partly-eroded, relatively-infertile horizons of the soils which are left after cultivation, or on native pasture damaged by wind erosion.

The agencies taking part in this work of revegetation will consist of the co-operating State experiment stations, especially those of Colorado, Kansas, Oklahoma and Nebraska. These State organizations are planning a co-ordinated attack, working in close association with the Soil Conservation Service through its Division of Research and, in the Division of Operations, the Section of Agronomy and Range Management and the Section of Conservation Nurseries. The Bureau of Plant Industry will also take part and assist in planning and carrying out portions of the

research work. The exact phases to be assigned to each of the respective co-operators have not been fully determined, but a brief outline of the scope of the research is given below.

This co-operation with the States listed above will apply especially to the southern Great Plains. In the northern Great Plains, the Division of Research is completing co-operative agreements with the States of Montana, Wyoming, North Dakota and South Dakota. One of the special objectives of these agreements is to obtain vegeta-

Regions of the Soil Conservation Service.

tive cover upon eroded pasture and range lands for direct erosion control. In addition, various phases of the wind erosion problem will be studied and methods will be evaluated for spreading and utilizing surplus run-off waters in order to obtain full use from the relatively variable precipitation.

As practically all aspects of soil conservation research are of direct or indirect interest to grassland and forage crop specialists in other parts of the world, we give below brief details of the terms of reference of the eight branches of the Division of Research in the SCS, although not all of these come directly within the scope of this Herbage Bulletin. They will, however, give a good indication of the comprehensive nature of the research on all aspects of the conservation of soil, water and vegetation in the United States, and may be a guide for the organization of similar programmes in other parts of the world. For the information regarding the organization of the two new sections we are indebted to the Assistant to the Chief, Division of Research, SCS (Dr. G. R. Stewart). Details of the first six sections are reproduced from Bulletin 25, pp. 136-8, with additional notes taken from the Report of the Chief of the SCS for the fiscal year ended June 30, 1938. In addition, there are included two further

notes, the first on the research contributions which have been made during the past years by the Office of the Division of Irrigation Investigations and the Division of Farm Drainage Investigations respectively ; the second on the preliminary outline of the new research in revegetation mentioned above.

Function and Scope of Division of Research, Soil Conservation Service

Office of Chief, Division of Research

The work of this Division is conducted through a Washington office and through eight section offices whose principal work lies in the field where erosion is most acute. The Office of the Chief formulates, establishes and co-ordinates major research policies, reviews and helps to develop the working plans through which the research is carried out. In the field, the Chief and his staff inspect and supervise projects, suggest improved procedures and aid in maintaining a proper scientific standard of research.

Soil and water conservation experiment stations

The studies under this project are directed towards developing and testing practices which are effective and practical for conserving and utilizing the soil and water resources on farm lands. The work is conducted from experiment stations, field stations, and laboratories representative of critical erosion problem areas, where local climatic conditions have produced similar problems of wind and water erosion. These investigations provide for the determination of soil and water losses under different land-use and farming practices and for different climatic, topographic, and soil conditions in various agricultural regions. In addition, the principal causes of soil and water losses are studied and this basic information is used in the development of practical agronomic and engineering methods for keeping soil and water on the farm. As conservation practices are developed and tested on the stations, they are applied to co-operating farms and their effectiveness is checked by conducting systematic evaluation surveys and practical field tests on work and demonstration projects.

Extract from Report of Chief, SCS, 1938. Sixteen experiment stations were engaged in the above research and four new sites were rapidly nearing completion.

A comparison of the effectiveness of dense protective cover and cultivated row crops is shown in table 1. Studies were initiated to determine the specific effects of different plant covers on run-off and erosion ; comparative figures are quoted for alfalfa, which intercepted 35.8 per cent of the rain that fell during the growing season, corn (maize) 15.5 per cent, and oats 6.9 per cent. Other factors equally or more important in the erosion process require study.

Dense vegetation almost always greatly reduced the rate at which water ran off the fields ; when total quantities of run-off were the same, the water from fields with dense vegetation moved at slower velocities and carried less soil.

In arid and semi-arid regions, studies of the effectiveness of water spreading were made. Run-off water which would otherwise have been lost was diverted to areas of low concentration by diversion dikes or ridges and used to develop vegetative cover. In some cases, high concentration of silt or soluble salts had a retardative effect on the growth of the vegetation. A study has been developed to determine the factors affecting the most profitable use of such diverted water.

Studies on the problem of wind erosion were limited to the reclamation and stabilization of one particular area ; plans are being prepared for a study of the fundamental causes of soil drifting.

Continuous research has been in progress to determine the infiltration rate of water in various types of soil ; one of the most important factors is soil structure, which in its turn depends largely upon organic matter content. Laboratory studies have indicated that the material removed from the soil by erosion contained a higher percentage of organic matter than the original soil in the field.

Table 1.– *Soil and water losses under cultivation and protective cover, from thirteen important soils representative of the principal types of erodible farm land within an area of approximately 250,000,000 acres.*

Soil type, location, and years of measurement	Annual rainfall for period	Slope	Clean-tilled			Dense cover			Time to remove 7 inches of soil		Approximate regional area*
			Crop	Annual soil loss per acre	Water loss as percentage of annual precipitation	Cover	Annual soil loss per acre	Water loss as percentage of annual precipitation	Clean tilled	Dense cover	
	Inches	Per cent		Tons	Per cent		Tons	Per cent	Years	Years	Million acres
Cecil sandy clay loam, Statesville, N.C., 1932-6	48.42	10.0	Cotton	25.08	10.47	Mixed grasses	0.014	0.29	46	82,150	41
Nacogdoches fine sandy loam, Tyler, Tex., 1932-6	42.34	10.0	do.	8.18	16.48	Bermuda grass	.006	.53	160	214,200	48
Kirvin fine sandy loam, Tyler, Tex., 1932-6.	41.77	8.75	do.	30.07	22.23	do.	.05	.91	46	27,400	
Shelby silt loam, Bethany, Mo., 1931-35.	34.79	8.0	Corn	68.78	28.31	Alfalfa	.25	7.49	16	4,540	18
Muskingum silt loam, Zanesville, Ohio, 1934-6. ..	36.46	12.0	do.	72.23	41.95	Bluegrass ..	.04	6.5	16	28,900	31
Clinton silt loam, La Crosse, Wis., 1933-5.	34.12	16.0	do.	88.66	20.84	do.	.03	2.82	11	33,600	22
Dubuque silt loam, La Crosse, Wis., 1934-5.	36.53	30.0	do.	81.44	19.12	do.	.22	6.83	11	4,110	
Vernon fine sandy loam, Guthrie, Okla., 1930-5 ..	33.12	7.7	Cotton	24.29	14.22	Bermuda grass	.032	1.23	50	38,200	37
Houston Black clay, Temple Tex.:											
1931-36	32.76	4.0	Corn	23.83	14.22	do.	.03	.04	34	26,700	8
1933-36	34.90	2.0	do.	10.62	13.38	do.	.10	.95	75	8,010	
Marshall silt loam, Clarinda, Iowa, 1933-5	26.82	9.0	do.	18.82	8.64	Bluegrass	.06	.97	48	15,200	23
Palouse silt loam, Pullman, Wash., 1932-35.	21.74	30.0	Wheat, fallow	8.52	9.40	Mixed grasses	1.45	3.71	130	740	8
	21.74	30.0	Bare	27.82	25.03	Spring wheat	1.65	3.23	38	650	
Colby silty clay loam, Hays, Kans, 1930-35.	20.36	5.0	Kafir	11.74	16.20	Native grass	.029	.30	91	36,900	10
Miles clay loam, Spur, Tex., 1926-37	20.73	2.0	Cotton ..	7.03	15.53	Buffalo grass	1.29	4.34	150	830	..

*Figures represent approximate acreage of soil types in the region specified.

Investigation of sedimentation resulting from erosion

The work under this project provides accurate information on the damage caused by sedimentation from erosion to reservoirs, stream channels, and to lower-lying agricultural land. Detailed surveys are being made in which the application of soil conservation measures to watershed areas can be justified to protect the public investments in water storage facilities. Determinations are likewise under way of the impairment of productivity of valley lands caused by the deposition of the infertile products of erosion. Studies are being made in natural streams to measure the total load of sediment carried and determine the manner in which sediment of different types contributed to filling reservoirs and stream beds. In addition, large scale laboratory investigations are being carried out to determine the hydraulic principles governing the entrainment, transportation and deposition of erosion debris.

Extract from Report of Chief, SCS, 1938. Work on reservoir-silting surveys was carried on by field parties, while the programme of stream and valley-silting investigations was concentrated mainly on the preparation of a report covering the relation of this type of sedimentation to culturally accelerated erosion. The construction of suitable equipment for measuring the movement of sediment along stream bottoms was completed at three stations in the Carolinas. The work of the hydraulic laboratory, established in co-operation with the California Institute of Technology to carry on fundamental research on the mechanics of sediment-laden flows, was continued along previous lines.

Watershed investigations of the effect of land-use practices on run-off as related to methods of control of erosion and floods

Investigations are made of the behaviour of water from the time it reaches the land as precipitation until it leaves the watershed as surface or underground flow. An evaluation is being made of the effects of physical characteristics of the land and its use, such as soil, topography, size and slope of drainage pattern, vegetative and crop cover, surface and underground storage, tillage methods and erosion control practices, as they affect storm run-off, stream flow and flood flows. These investigations are conducted experimentally on entire watersheds of suitable areas and are carried out extensively by sampling plots for responses in run-off and erosion. Two intensive experimental studies and one extensive study are under way. The intensive studies include those of watersheds of approximately 5,000 acres each and are established, one in the Muskingum Watershed Conservancy District in Ohio, and the other in the Brazos River Conservation and Reclamation District of Texas. The extensive study is conducted within the Central Great Plains with headquarters at Lincoln, Nebraska. Determinations are also being made of the rates and amounts of run-off in agricultural areas within work project areas for use in the economic design of erosion control, flood flow control and hydraulic structures.

Extract from Report of Chief, SCS, 1938. The first objective of the studies conducted on the large experimental watersheds (catchment areas) is to determine quantitatively the effect of improved land use and erosion-control practices on soil and water conservation for the agricultural regions represented. The second is to find the extent to which these practices can be effective in the control and reduction of floods, as well as in sustaining and augmenting stream flow during periods of dry weather. Certain experimental watersheds in Ohio and Texas, each about 5,000 acres in size, have been divided into smaller watersheds of different sizes on each of which various conservation practices were applied after determination of size, slope, soils, etc. Precipitation, stream flow, ground-water levels, soil losses, crop yields, and many other factors were included in the observations. An important development in Ohio was the expansion of flood studies being made in co-operation with the Muskingum Watershed Conservancy District.

In co-operation with the Division of Operations, the Section continued to establish run-off studies on demonstration project areas, in order to supplement eventually the more detailed work conducted on experimental watersheds, and to provide data for use in the design of various hydraulic structures.

An important activity has been the initiation of simulated rainfall investigations, further progress having been made in the development of a portable sprinkler apparatus, whereby artificial rainfall, in various amounts and intensities, was played upon plots in order to study the relationships of rainfall, run-off and erosion under controlled conditions.

The programme of hydraulic laboratory investigations has been developed to cover the following principal objectives: (1) to increase the dependability and to decrease the cost of the hydraulic works used in soil and water conservation, and (2) to develop technical equipment for use in soil- and water-conservation research. Valuable information has been derived from tests of channels protected with the various types of vegetation frequently used in meadow strips and grassed waterways. These tests revealed the relative protection afforded by Sudan grass, *Lespedeza sericea* and common lespedeza, as well as providing data on the hydraulic characteristics of waterways lined with such vegetation. The results of some of these tests are summarized in Table 2 to show the remarkable protection against scour afforded by vegetal channel linings, and the profound effect of vegetation on the hydraulic characteristics of channels.

Table 2.—*Summary of results of tests of vegetal linings in small channels*[1] *at the Spartanburg Outdoor Hydraulic Laboratory*

Kind of channel lining	Value of Kutter's n	Probable safe velocity[2]	Kind of channel lining	Value of Kutter's n	Probable safe velocity[2]
	Coefficient of roughness	Feet per second		Coefficient of roughness	Feet per second
Bermuda grass—solid sod	0.035	8	Sudan grass	0.033	5
Lespedeza sericea	0.038	3	Bare[3]	0.018	1
Common Lespedeza ..	0.037	4			

[1] Bermuda grass channel had bottom width of 1 ft. and side slopes 1 in 1. All other channels had bottom width of 3 ft. and side slopes of 1 in 3. Maximum test flows somewhat exceeded 14 cubic feet per second.

[2] For good cover and short periods of run-off with recovery periods intervening.

[3] Test of bare channel made to provide basis for evaluation of the effectiveness of the vegetal linings. The soil in the bare channel was the same as that in the three channels lined with Lespedeza and Sudan grass.

Co-operative studies of the Service with the Geological Survey and the State agricultural experiment stations were continued, data being collected on precipitation, stream-flow, silt movement, and ground-water fluctuations. A more pressing need for research in hydraulic data and related information has led to the inception of a project for the collection of meteorological and other types of hydraulic data from many sources, and their compilation in a convenient and up-to-date form.

Investigations of the geographic and climatic factors related to erosion

This project is concerned with the study of the physical factors such as climate, plant cover and geographic environment, which notably affect soil erosion. Climatic studies attempt to delimit the climatic regions of the country in order to determine the frequency of storms and rainfall, and show their influence on soil erosion and the occurrence of droughts. Field studies are being carried out to find the relation of the bed rock, soil type, climate and vegetation to gully cutting, sheet wash and wind erosion. Ecological research is being used to determine the nature of plant succession on eroded areas and to find the best methods of controlling erosion through artificial plant covers. Studies in the history of erosion not only show its early occurrence, but also trace the attempts which have been made to correct the trouble, both in the United States and in foreign countries.

Extract from Report of Chief, SCS, 1938. The study of rainfall-run-off relations will help to make it possible to determine the effect of land use on floods, which is one of the primary research objectives at the present time. The climatic information being obtained makes it possible to treat each rain-storm as an individual event and permits isolation of the various influences that produce variations in the rainfall-run-off relationships. Immediate practical value is attached to the statistical research which the Section conducted on precipitation intensity-frequency. It has been recognized that the methods in common use for determining rainfall intensity-frequency are inadequate for use by engineers in designing soil-conservation and flood-control structures. A method recently developed by the Section for revising storm frequencies obtained by the station-year method calls for the determination on a statistical basis of the amount of correlation between rainfall stations for storms of specified size. From these data the number of valid station-years in the record was ascertained. The method is thus simply an application of the statistical technique used for testing persistency in observations taken at equal time intervals.

One of the major problems in developing the programme of physiographic research was caused by the fact that observational work of this type was unfamiliar to agricultural research workers. Since physiographers and geologists have given relatively little attention in the past to soil erosion, research projects were set up to study a variety of physiographic processes in widely contrasting regions, for example, the study of soil erosion in the limestone lands of Western Kentucky (*Herb. Abstr.* 9. Abs. 839. 1939, and *USDA. Tech. Bull.* 633. Jan. 1939, and see *Herb. Abstr.* 9. Abs. 1260. 1939). Field studies were initiated to determine the agricultural significance of mass movements of soil such as soil creep, earth flow and slumping.

Investigations of the economics of soil and water conservation

The work under this project is designed to develop an economic appraisal of the current soil-conservation programmes, and to provide suggestions for their improvement. This appraisal is being developed through a determination of the changes in the ownership, operation and financial organization of farms, ranches and orchards and in the income and standard of living of their operators, brought about both by erosion and by an erosion-control programme, as well as by the effect of the latter agencies on non-agricultural individuals, institutions and communities. Further, this appraisal involves a determination of the damage sustained by the public through the destruction of land by erosion, the accumulation of erosion debris on roads, in streams and in reservoirs ; the cost to the public of erosion control ; and finally, a measurement of the public benefit to be gained from a co-ordinated programme of soil and water conservation.

Co-operative investigations of erosion-resisting plants of economic value (" Hill culture ")

Many millions of acres of agricultural land must be retired from clean-tilled cultivation incident to accomplishing the national programme of soil and water conservation. The annual cash returns from uncultivated vegetation, such as ordinary forest cover or pasture, are frequently too low to justify the average farmer in discontinuing cultivation to the extent called for in the erosion-control plans. The work of this project is centred on the attempt to find superior types of erosion-resisting plants and covers having high economic possibilities. Tests are being carried out with such plants on a variety of soils to determine their adaptability to different climatic regions and to improve vegetation methods for the dual purpose of erosion control and economic use. Experiments are being initiated on the selection and breeding of new plants as well as on economical methods of propagation. Research is also planned on the utilization of the products, which it is hoped may have a wide variety of uses ranging from human and livestock food to new sources of tannin, fibres and vegetable oils. The work is done in co-operation with many State and Federal subject matter agencies.

Extract from Report of Chief, SCS, 1938. Research along these lines, conducted in conjunction with the Bureau of Plant Industry, has been established in co-operation with the agricultural experiment stations of Alabama, California, Iowa, Maryland and Ohio, each project repre-

senting a distinct plant-growth region where the work was urgently needed. Progress has been made in the development of new and more practical methods for propagating desirable erosion-control planting stock through direct rooting of hardwood cuttings of certain species. For example, it is now possible to reproduce the shipmast locust, *Robinia* sp., by hardwood cuttings at low cost, whereas previously this valuable farm tree was not available because the stock was limited and reproduction was possible only by root cuttings or sprouts at a cost that was prohibitive.

Irrigation Investigations

The research work of Irrigation Investigations in the United States Department of Agriculture has related principally to the need for irrigation, the means of supplying the water, the methods of reducing waste, and the organization and administration of community irrigation enterprises. The work was begun in the Office of Experiment Stations, transferred to the Bureau of Public Roads in 1915, and included in the Bureau of Agricultural Engineering when that was established in 1931.

Irrigation requirements

Increasing demands upon limited water supplies and increasing costs of stored or transported supplies have been studied by Irrigation Investigations continuously from the beginning, in order that the available water might be used most economically and profitably. The results of experiments by Federal and State agencies in the yields of different crops in different localities and on different soils, with different quantities of irrigation water, together with analyses of farm irrigation practices and conditions, and consideration of kinds and values of crops, local precipitation and temperatures, and availability of water, have been used to determine the seasonal and monthly net irrigation requirements in acre-feet per acre for each of the 96 divisions into which the West was divided. From these studies have come greater economy in use of water and expansion of the irrigated acreage, increasing the prosperity of the farmers and of the States of the Arable Lands of the Great Basin. Fortier. Irrigation requirements of the arid and semi-arid lands of the Missouri and Arkansas river basins. U.S. Dept. Agric. Tech. Bull. 36. 1928. Fortier and Young. Irrigation requirements of the arid and semi-arid lands of the South-west. Tech. Bull. 185. 1930. Fortier and Young. Irrigation requirements of the arid and semi-arid lands of the Columbia river basin. Tech. Bull. 200. 1930. Fortier and Young. Irrigation requirements of the arid and semi-arid lands of the Pacific slope basins. Tech. Bull. 379. 1933.

Conservation of Water

The increase in acreage irrigated wholly or partly by pumping from wells has resulted in a generally continuous lowering of the ground water table over large areas, the drop in water elevation amounting to 15 to 245 feet in different districts in southern California. This greatly increases the cost of irrigation and suggests the possibility that the demand might soon exceed the water supply. Floods from torrential precipitations have been passing unused to the ocean, over fan-shaped cones of boulders, gravel, and other coarse debris at canyon mouths, where the ordinary flow is absorbed. Experiments made in co-operation with Californian agencies have demonstrated the feasibility of obtaining subsurface storage of a large amount of these freshet flows by spreading them over the absorptive materials. Highest percolation rates have been maintained on tracts growing native vegetation with soil covering least disturbed. (Mitchelson and Muckel. Spreading water for storage underground. Tech. Bull. 578. 1937.)

Scarcity of water has brought consideration of the feasibility of utilizing sewage for irrigation, and investigation has been made of the practicability of this source of water supply and the public health aspects of such use. Hutchins. Sewage as a supply of water for irrigation in Western States. Tech. Bull. 675. 1939. (in press).

Advance knowledge of the flow in streams supplied by mountain snows permits planning irrigation practices to utilize most profitably the total water that will be available, and to operate storage reservoirs to reduce peak flood flows. Methods for measuring the water storage in snow

cover during winter and spring, developed under the co-operation of Federal and State agencies, have resulted in the accurate forecasting of water supplies, and have thus prevented or reduced losses of growing crops and damages from stream floods. (*Bur. Agric. Engng. Ann. Reports,* 1938 and earlier).

Flow in Irrigation Conduits

As expansion of the irrigated acreage has necessitated transportation of water over greater distances, the economic importance of efficiency in carrying capacity of the conduits has increased. In order that ditches and pipes for conducting irrigation water may be designed for adequate capacity and minimum cost, and that the deteriorating effects of age and the obstructing effects of vegetation may be forecast, many hundreds of observations and tests have been made with great care, on all usual kinds of conduits and under a wide range of conditions. The studies included ditches in earth and in rock, some with concrete lining ; pipes of wood staves, of steel, and of concrete ; and flumes of wood, of metals, and of concrete. The effects of changes in velocity and depth of flow, in original and acquired roughness of the wetted perimeter, and in slope, curvature, and uniformity of cross-section of the stream were examined, and determinations were made of the empirical coefficients in formulae used for computing flow. Tables of capacities and diagrams for estimating flow were developed. The results have become generally accepted as a standard for design of irrigation works in the United States. Scobey. The flow of water in wood-stave pipe. Dept. Bull. 376. 1916. Scobey. The flow of water in concrete pipe. Dept. Bull. 852. 1920. Scobey. The flow of water in riveted steel and analogous pipes. Tech. Bull. 150. 1930. Scobey. The flow of water in flumes. Tech. Bull. 393. 1930. Scobey. Flow of water in irrigation and similar channels. Tech. Bull. 652. 1939. (in press).

Evaporation

Losses of water by evaporation from reservoirs reduce the supplies available for application to crops. While these losses are largely unavoidable, knowledge of their amounts permits more accurate calculation of the sufficiency of proposed or constructed storage facilities for particular areas, and of the economy of measures that might reduce evaporation. Experiments, both indoor and outdoor, in co-operation with the Colorado Agricultural Experiment Station, have been made on the effects of air and water temperatures, wind movement, barometric pressure, area of water surface, and type of evaporation pan upon the rate of evaporation. The results have been expressed in formulae covering a wide range of conditions, and have developed coefficients for applying observations made with different types of evaporation pans to calculation of losses from large reservoirs. Sleight. Evaporation from the surface of water and river-bed materials. *J. agric. Res.* 10. 209-62. 1917. Rohwer. Evaporation from free water surfaces. Tech. Bull. 271. 1931.

Measurement of Water

Economy in use of irrigation water and equity in the apportionment of communally-owned supplies demand correct measurement of the flow under conditions of varying flow, frequently with considerable trash and sediment in the water, and commonly with a loss in utility increasing with the loss of head or elevation in passing through the measuring device. Studies in co-operation with the Colorado Agricultural Experiment Station have developed the Parshall measuring flume, in appearance somewhat resembling a Venturi meter for measuring flow in pipes, which, in structures of 6-inch to 50-foot throat, has a capacity from 0.1 to 3,300 second-feet. By means of an integrating device, a continuous record is made automatically of the flow through the flume. By reason of its simplicity in operation, economy in loss of head, and freedom from obstruction by trash or sediment, it is becoming the standard flow measuring device in large sections of the West. Cone. The Venturi Flume. *J. agric. Res.* 9. 115-29. 1917. Parshall. The improved Venturi flume. *Colorado Agric. Expt. Sta. Bull.* 336. 1928. Parshall. Parshall flumes of large size. *Colorado agric. Expt. Sta. Bull.* 386. 1932.

Soil Moisture

The effective and economical use of water in irrigation requires knowledge of soil-moisture movement, both horizontal and vertical. Capillarity affects the distribution of moisture to plant roots between irrigation furrows, causes alkali concentration in surface soil, and aids gravity in causing loss of water by deep percolation. Studies have produced important information as to the rates and quantities of water moved by capillarity, and the influence of distance upon this force. McLaughlin. The capillary movement of soil moisture. Dept. Bull. 835. 1920. McLaughlin. The capillary distribution of moisture in soil columns of small cross-section. Dept. Bull. 1221. 1924. Lewis. Rate of flow of capillary moisture. Tech. Bull. 579. 1937.

Profit in the production of crops, especially in areas where water is limited in amount or is high in cost, requires economy in use of the water together with application of sufficient quantities at proper times to avoid reduction in yield. Studies in co-operation with the Oregon Agricultural Experiment Station have shown that the rate of fruit growth of pears is closely related to the moisture content of the upper 3 feet of soil, yet too much moisture causes fruits of undesirably large size. Also, because rate of growth is greatest rather late in the season, a low moisture content then has more effect than an equally low content earlier. Experiments in southern California have developed methods of determining, by measurements of rate of fruit growth and of soil moisture content, when and in what amounts irrigation water should be applied to individual citrus orchards. Lewis, Work and Aldrich. Studies of the irrigation of pear orchards on heavy soil near Medford, Oregon. Tech. Bull. 432. 1934. Taylor and Furr. Use of soil-moisture and fruit-growth records for checking irrigation practices in citrus orchards. Circ. 426. 1937.

Irrigation Institutions

Where agriculture is largely dependent upon irrigation, and the obtaining of water requires co-operation of many landowners and even outside financing, the legal aspects of acquiring and equitably apportioning water are exceedingly important. Extensive studies have been made relative to irrigation institutions and customs, and the results have been utilized by authorities formulating the irrigation laws of western States. Teele. The western farmer's water right. Dept. Bull. 913. 1920. Hutchins. Mutual Irrigation Companies. Tech. Bull. 82. 1929. Hutchins. Commercial Irrigation Companies. Tech. Bull. 177. 1930. Hutchins. Irrigation districts, their organization, operation, and financing. Tech. Bull. 254. 1931. Hutchins. Policies governing the ownership of return waters from irrigation. Tech. Bull. 439. 1934.

Silt and Debris in Streams and Reservoirs

When water for irrigation is taken from streams heavily laden with silt, like many in the South-west, deposition of the sediment on the land and in the ditches commonly necessitates considerable expense for moving or removing the material, and deposition in reservoirs reduces their capacity, sometimes so rapidly that the construction is not profitable. Investigations, partly in co-operation with the Texas Board of Water Engineers, of the quantities of silt carried in Colorado River and other streams and of the deposition of it in reservoirs have shed light on the probable effective life of Boulder Dam and other storage structures. Fortier and Blaney. Silt in the Colorado River and its relation to irrigation. Tech. Bull. 67. 1928. Faris. The silt load of Texas streams. Tech. Bull. 382. 1933.

In sections where stream floods in mountainous areas carry heavy loads of gravel, boulders, and detritus from the canyon mouths, protection of irrigation ditches and reservoirs is an acute problem. A study in co-operation with the Utah Agricultural Experiment Station developed a method of unloading such streams of the debris before it reaches the irrigation works. Winsor. The Barrier System for control of floods in mountain streams. Misc. Publ. 165. 1933.

Application of Research Results

The major results of the irrigation studies are generally published for use by farmers, or by engineers or other representatives of community enterprises. Particular application of the results of the research work in irrigation has been made by the Division of Irrigation for the benefit of

landowners and bond-holders in appraising the resources of certain irrigation enterprises ; and for the Farm Credit Administration of large areas such as the Lower Rio Grande Valley in Texas and the Imperial and Coachella Valleys in California, concerning the eligibility of the lands for Federal farm loans. Hutchins. Financial settlements of defaulting irrigation enterprises. Circ. 72. 1929. (Manuscript reports to Farm Credit Administrations.)

Farm Drainage Investigations

The research work of Drainage Investigations in the U. S. Department of Agriculture deals mostly with the methods and materials practicable for use in farm drainage and the bases for designing drainage works.

Durability of Concrete Tile

Failure of concrete tile in soils containing so-called alkalis instigated the establishment in 1920 of a project in co-operation with the University of Minnesota for determining a means of avoiding such losses. The years of experimentation that followed (not yet ended) have shown that the active agents of deterioration are usually the sulphates of magnesium ($MgSO_4$) and sodium (Na_2SO_4) ; that certain Portland cements resist destruction by these salts for ten times the life of some other cements similarly exposed ; that a long period—90 days or more—of air hardening before contact with sulphates increases the alkali resistance of the tile ; that steam-curing at temperatures of 212° F. or higher, when the tiles are 12 to 24 hours old, makes for higher resistance ; and that addition of a proper quantity of calcium chloride to the mix, supplemented by curing in water vapour at temperatures of 150° to 350° F., according to length of curing period, produces a highly alkali-resistant concrete.

The experiments have included tests of 158 brands of Portland cement from 103 American and European mills, and of many hundred-thousands of concrete specimens which have comprised some briquettes and some tile but mostly cylinders of 2 inches diameter and 4 inches length. These have been stored for periods of up to 10 years in sulphate solutions of different strengths, and in Medicine Lake, South Dakota, where the concentration is about 14 per cent. In the course of this study it was found that the deterioration of a test cylinder could be determined from the elongation measured with an Ames dial, thus obviating the necessity for destroying each specimen as tested and making it possible to record progressive deterioration in the same specimens.

This investigation has induced many manufacturers to produce more durable cements and concrete products, and has practically eliminated the risk of concrete tile failing from alkali action in the central and eastern States. Miller and Manson. Laboratory and field tests of concrete exposed to the action of sulphate waters. Tech. Bull. 358. 1933.

Field experiments with concrete tile in acid peat soils in the North Central States, now continued for 10 years, have shown that the soil acids do little damage to tile of good concrete but do much damage to tile of low quality. Density and strength are indications of comparative quality for this use.

Tile Drains and Culverts

Accurate computation of the capacities of tile drains becomes increasingly important with increase in size of tile used, because cost increases more rapidly than size. A series of more than 800 tests was made of drain tile lines laid in earth in a wooden flume about 600 feet long adjustable in slope from zero to 1.5 per cent, using clay tile and concrete tile of 4 inch to 12 inch diameter, flow depths of 0.5 to full diameter, and also tests of care in laying, representative of good and of poor workmanship. The results disclosed that well-laid tiles have capacities of about one-fourth greater than commonly estimated with the Kutter-Chezy formula, using a roughness coefficient of 0.013, and developed a relatively simple formula for velocity, $V = 138\ R^{2/3}\ S^{1/2}$, applicable to both clay and concrete tile laid with reasonable care. Yarnell. The flow of water in drain tile. *U. S. Dept. Agric. Bull.* 854. 1920.

A study of the capacities of culverts, comprising 3,300 tests of pipe and box structures, was made in co-operation with the University of Iowa. The comparison of pipe culverts 30 feet long

showed vitrified clay pipe of slightly greater capacity than concrete pipe at 12 inches diameter, and equal capacity at 30 inches diameter, and either of these carrying 30 to 50 per cent (65 per cent in the extreme case) more than corrugated iron pipe of the same diameter. Placing the bevelled lip of concrete pipe, or the bell end of vitrified pipe, upstream increased the culvert capacity by 5 to 14 per cent over the capacity with square cornered entrance. Similar effects were obtained with box culverts by rounding the entrance corners, and increased capacity was obtained by flaring the outlet portion. The general results have been expressed by graphs and formulae extremely valuable in the economical design of culvert structures. Yarnell in collaboration with Nagler and Woodward. The flow of water through culverts. Univ. of Iowa. Studies in Engng. Bull. 1. 1936.

Open Channels

The capacities of open drains, both artificial and natural, of moderate and of large size, have been the subject of study over a long period. In all, some 565 measurements have been made on sixty-five different selected courses in eight States, to determine the capacities at different seasons of the year, and for different conditions as regards amount of vegetation in the waterway, uniformity of stream cross-section, and occurrence of debris. The results have been expressed as determinations of the roughness coefficient in the Kutter formula for flow in open channels, which have been made on a broader foundation, with more certainty, and in more detail than have been presented elsewhere as relating to drainage. They not only make possible the design of most economical ditch systems, but also show the benefits of keeping drainage channels cleared of debris and constructive vegetation. Ramser. The flow of water in drainage channels. *Tech. Bull.* 129. 1929.

Reduction in the capacity of drainage ditches has been frequently due to the deposit of soil carried in the water, and damage to bordering lands and lands further down the drain has resulted in many instances from enlargement of the channel by erosive action of the stream. The adjustment of velocities to the materials through which the stream flows is properly a matter of concern for designers of ditch systems. Measurements of channel cross-section and flow were made on twenty-two ditches in Iowa, Tennessee, and Mississippi over periods of several years, and the nature and rate of change in size and shape of the channel were determined, together with the conditions that caused the changes. The effects of such factors as sloughing banks, backwater, variation in water stages, silt charges of the stream, variation in grade of channel, and volume of run-off water were analysed, and the results prepared for convenient use in designing drainage ditches for permanence and easy maintenance, or for utilizing the erosive action of the water to assist in excavating the desired waterway, which is practicable in some circumstances. Ramser. Erosion and silting of dredged drainage channels. Tech. Bull. 184. 1930.

Bridge Piers and Channel Bends

Bridge piers and pile trestles constitute obstructions to flow which are not readily eliminated from drainage channels, yet occur most frequently in places where widening of the channels to compensate for the obstructive effects is especially costly—in urban areas. Experiments with model and full-scale piers and trestle bents in different depths and different velocities of flow less than critical were run in co-operation with the University of Iowa, to study the effect of such structures in raising the water level, as is necessary to force the flow through the lessened open width of waterway, and the efficiency of different pier shapes in reducing the backwater effects. Values were determined for the empirical coefficient in different formulae commonly used for computing the obstructive effects of trestles and piers. The results with trestles show that a 10-pile bent causes twice the backwater rise caused by a 5-pile bent; that two offset 5-pile bents, as for a double track railway, cause more backwater rise than one 10-pile bent; and that bents cause a backwater effect 50 to 75 per cent greater when at an angle of 30° than when parallel to the direction of flow. Yarnell. Pile trestles as channel obstructions. Tech. Bull. 429. 1934. The results with piers showed that twin-cylinder piers, either with or without connecting diaphragms, and piers with 90° triangular noses and tails, although more efficient in passing the

flow than are piers with square noses and tails, are less efficient than those with noses and tails semi-circular or lens-shaped. Yarnell. Bridge piers as channel obstructions. Tech. Bull. 442. 1934.

To study more analytically the loss of head and erosional effects of bends, piers and other obstructions to flow in drainage channels, experiments in flow around bends in 10-inch by 10-inch and 5- by 10-inch rectangular channels and in 6-inch pipe were conducted in co-operation with the University of Iowa. Transparent pyralin was used for both series to observe the phenomena more readily. The changes in velocities, pressures, and total energy of different filaments of flow were determined, and the loss of head, for different quantities of flow. Yarnell and Woodward. Flow of water around 180-degree bends. Tech. Bull. 526. 1936. Yarnell. Flow of water through 6-inch pipe bends. Tech. Bull. 577. 1937.

Run-off

A fundamental consideration in the design of drains is the quantity of water that must be carried. No rational quantitative analysis has been made of the relation of run-off to the precipitation from which it results, because of the intricate and undetermined relationships involving evaporation, transpiration, temperature, soil moisture, and other conditions. The estimate of required capacity of a drain depends, therefore, upon judicious application of compiled data as to precipitation upon more or less comparable drainage basins and accompanying rates of run-off. Measurements of run-off from agricultural areas of varied size have been made on a large number of streams and ditches in many of the Central and South-eastern States, which have been useful to many engineers designing drainage improvements. Okey. Run-off from the drained prairie lands of southern Louisiana. *J. agric. Res.* 11. 247-79. 1917. Ramser. Run-off from small agricultural areas. *J. agric. Res.* 34. 797-823. 1927. (Also mimeographed reports in Bur. Agric. Engng.)

Pumping for Drainage

Drainage of some very fertile lands in Illinois and Mississippi Rivers requires pumping of all or a large part of the run-off, while levees hold the river floods too high for gravity outlet to be obtained. Pumping must be intermittent and irregular, and a large reserve capacity is necessary for occasional heavy precipitation during high floods. Therefore, the problem of selecting equipment, which is most economical when investment, depreciation, and operation costs are combined, is less simple than for a plant for steady operation. Inaccessibility for delivery of fuel, and charges for peak electric power availability complicate the problem. Data have been collected and studies made over a number of years determining the quantities of run-off to be pumped by such drainage plant, the power required, the costs of the pumping, the kinds of equipment and power best suited to the different conditions, and the most economical methods of operation. Tests of the mechanical equipment have been made, and analyses of the costs, including methods of charging for electric power and for reserve power, and the different types of equipment have been compared for different situations and conditions of operation. Sutton. Cost of pumping for drainage in the Upper Mississippi Valley. Tech. Bull. 327. 1932. Sutton. Design and operation of drainage pumping plant in the Upper Mississippi Valley. Tech. Bull. 390. 1933.

Drainage of Peat Soils

Drainage and cultivation of the muck and peat soils of the coastal prairie lands of Louisiana and Southern Florida are accompanied by a marked subsidence of the land surface. This may be as much as 4 inches at the first ploughing, but the rate decreases rapidly with use of the land. However, it has amounted in some places to 3 feet in the first three or four years, and apparently reaches ultimately a rate of about 1 inch per year. This subsidence requires an increase in the depth of drainage ditches, and in the lift of the pumping which is commonly necessary for the run-off from these lands. The results of the studies conducted in these districts permit estimation of the period for which these lands may be utilized for farming, where the soil is but a few feet

deep over rock or other untillable subsoil. Okey. The wet lands of South Louisiana and their drainage. Dept. Bull. 652. 1918. Clayton. Subsidence of peat soils in Florida. (Mimeo. Publ. Bur. Agric. Engng. 1936.)

Revegetation

A. Problems relating primarily to the utilization in soil erosion of promising species, varieties or selected strains, as for example :

1. Mass propagation of grasses and other plants promising for erosion control
2. Determining the adequacy of various methods of securing stands on eroded lands
3. Collection and testing of native species for erosion control efficiency
4. Determining species composition of native meadows for information relative to re-seeding
5. Bulk seed collection
6. Adaptation seedings on different soil types and fertility levels to determine erosion-control efficiency

B. 1. The breeding and improvement of species
   a. Studies of anthesis and pollination
   b. Determination of chromosome numbers
   c. Selection and establishment of pure lines of promising varieties and strains
   d. Production of new varieties and strains by hybridization
2. Agronomic and physiological research to establish successful methods of planting grasses and other plants
   a. Reaction in relation to environment of individual species in pure stands
      (1) Seasonal productivity or herbage production at definite intervals during the year
      (2) Effect of different degrees of defoliation on productivity and longevity
      (3) Chemical composition of leaves, stems and roots under different degrees of defoliation
      (4) Correlation of herbage yields and chemical composition with soil moisture, soil temperature, air temperature, soil fertility, and other environmental factors
   b. Reaction in relation to environment of various plants in mixtures
      (1) Seasonal productivity
      (2) Relative permanency of each component species
      (3) Effect of ecological factors on plant behaviour
      (4) Effect of competition on roots, leaves, stolons, rhizomes, and seed development of component species
   c. Factors affecting the use of grass and other plants in crop rotation
3. Pathological research
   a. Etiology of disease
   b. Control methods
   c. Co-operation with plant breeders in development of disease-resistant varieties and strains
4. Grazing research (co-operative)
5. Germination problems of special significance, as may be mutually agreeable.

DIVISION OF CONSERVATION OPERATIONS, SOIL CONSERVATION SERVICE

Section of Agronomy and Range Management

Extract from Report of Chief, SCS. 1938. It has become more and more apparent that effective soil and water conservation can be achieved most practically and economically through the use of vegetative-control measures. In consequence, greater emphasis has now been placed on agronomic and range management practices. New and better crop rotations have been developed for the various regions; cultivated fields suffering from severe erosion have been retired to grass or other protective vegetation; pastures and range lands have been improved by liming, fertilizing and adjusting grazing to productive capacity. The use of cover crops has become widespread in certain regions, and vegetation has also been used extensively to supplement engineering structures, such as terraces, diversion ditches and check dams in gullies. Considerable progress has been made in establishing vegetative waterways in connexion with strip cropping and terracing. In the south, *Lespedeza sericea* and Kudzu have been extensively used for this purpose; cheaper methods of establishing vegetation, particularly Bermuda grass (*Cynodon dactylon*), in outlet channels have been developed (see Table showing results from Spartanburg, p. 33). Efforts have been made to take advantage of natural waterways, which could be developed into productive meadow or pasture land, and at the same time serve as outlets for surplus run-off.

Crop Land Management

Definite changes have been noted in cropping practices, and a significant reduction in the acreage of clean-tilled crops. There has also been an increase in acreage of winter cover crops amounting on some projects to more than 100 per cent. New plants are now being used, for example, early southern giant bur clover (*Medicago denticulata*), which has been adopted because of its early maturing qualities, prolific vegetative growth, and its value as an erosion-control and soil-improving crop. There has been a marked increase also in the production of crimson clover (*Trifolium incarnatum*) and *Crotalaria*.

Refinements in the practice of strip cropping emphasize the need for staying close to the contour, both at the top and bottom of the strips. In the Cotton Belt the development of permanent strip cropping has been an outstanding accomplishment. In portions of the Great Plains, excellent progress has been made with alfalfa-brome grass mixtures in contour buffer strips, which serve to check run-off. The amount of grass included in mixtures of alfalfa and other legumes has been greatly increased, both in rotation and permanent meadows, as such mixtures are more valuable in securing good meadow stands and in increasing the organic matter of the soil. Considerable progress has been made in the development of grass and legume silage in the north-eastern and middle-west regions, a development which is of

particular value in providing good feed during the summer months when permanent pastures are unproductive. It also decreases the acreage of corn necessary for winter feed.

Orchard Management

An outstanding development has been the increased use of cover crops. On the Pacific coast permanent cover has been established in both deciduous orchards and citrus groves where clean cultivation or the use of annual cover crops had formerly been established practices. The application of fertilizer or manure to orchard cover crops has become a standard practice in some sections. There has also been a marked increase in contour planting and mulching. Clean cultivation of vineyards has long been considered necessary in the production of grapes, but it has been found in California that annual volunteer cover or green manure crops treated with fertilizer or manure were effective in controlling wind and water erosion in vineyards.

Pasture Management

With the retirement of considerable acreage from cultivation, increased attention has been given to the development of new pastures and meadows. In many sections supplementary pastures are provided to ensure adequate livestock feed throughout the growing season. The use of contour furrowing has increased ; in the establishment of new pastures and the renovation of old pastures a system of contour furrowing was devised, which left a series of furrows and ridges adjacent to one another in the field. This was accomplished by back furrowing and dead furrowing with a plough and resulted in shallow, wider flat-bottom furrows that conserve moisture over nearly the whole surface of the pasture, rather than in narrow ribbons.

Range Management

The major development in range management has been the adoption of standard methods of range survey known as western range survey standards (article on this question to appear in an early issue of *Herbage Reviews*). Limitation of number of live stock to carrying capacity, better distribution of grazing through the erection of fences, development of watering places, proper seasonal use of the range, and better planned salt distribution led to striking improvements in pasture and range vegetation.

Forage requirement studies made in co-operation with other agencies led to a much better understanding of carrying capacity of different range areas. The grazing of rotation crops was studied to determine what amount of grazing would still leave sufficient residues for turning under as green manure. In the Pacific Northwest sweet clover and grass seedings made in the spring would carry one-half of an animal unit per acre per month after the plants had reached a height of about 12 inches, without decreasing the second year yield, or impairing the protection provided for the soil during the winter. Second-year sweet clover and grass, after it has reached a height of 10 to 12 inches, will still carry two animal units per acre per month. The use of rotation crops in relieving range and pasture land is now an important factor in range and pasture improvement.

SOIL CONSERVATION SERVICE

RESEARCH IN PUERTO RICO AND THE VIRGIN ISLANDS

Research work of the Soil Conservation Service in Puerto Rico is directed towards the development of methods for stabilizing soil under the peculiar agricultural conditions prevailing on the Island, where the density of population virtually forces land with slopes of as much as 80 per cent to be cultivated. Initial experiments made in co-operation with the Federal Experiment Station showed the possibility of building practically flat bench terraces where the sloping banks were stabilized by close-growing grass or cover plants. Hand-labour was used at first, but less expensive methods of building these bench terraces are now being developed by planting stiff-stemmed upright growing plants, such as elephant grass, on the contour at a vertical distance of about 4 to 5 feet between the terraces. The terraces were gradually developed by ploughing the soil along the contour at each period of cultivation. A portion of the soil was lodged against the vegetative barrier, and a relatively level bench or terrace was gradually formed by accumulations of silt.

A conference has been held between the SCS representatives in Puerto Rico, and the Governor of the Virgin Islands. Plans were developed for a soil and water conservation survey of St. Croix, St. Thomas and St. John. Definite conclusions are not yet available, but preliminary work indicated a number of areas where dams could be located to impound water, which could be used later for watering live stock or for irrigation.

UNITED STATES GOLF ASSOCIATION

The amount of experimental work at Arlington Turf Gardens in the vicinity of Washington, D.C. has greatly increased. New series of plots devoted to tests of species of *Agrostis*, *Poa*, *Festuca*, *Cynodon* and *Zoysia* have been planted to determine the value of recently developed strains. Observations were continued on disease resistance, colour density, etc. on many plots of these grasses. A large new nursery has been planted with more than 150 separate strains of grasses and more than 12,000 linear feet of nursery rows have been planted to creeping bent (*Agrostis* sp.). Experiments have been conducted on different methods of planting *Poa pratensis* and *Zoysia* by the vegetative method.

Some of the grass breeding work consists of growing selfed plants of bluegrasses (*Poa* sp.) and fescues. These selfed strains are compared in both individual plant studies and in turf plots for uniformity, vigour and rhizome or stolon production.

The Green Section has continued its policy of checking experimental results obtained at Arlington with further tests on golf courses throughout the United States under a wide variety of soil and climatic conditions.

Other studies carried out by the Association include the effect of fertilizers, the use of chemical weed killers, the obtaining of weed-free topdressing at a reasonable cost, the effects of and methods of applying fungicides to control turf diseases, and soil improvement on golf courses.

DIVISION OF PLANT BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON

The work of this Division is divided into seven chief sections, as follows :

Biochemical investigations
Experimental taxonomy
Investigations on the cambium and its derivative tissues
Desert investigations
Ecology
Historical climatology
Palæobotany

The biochemical investigations include studies on leaf pigments (carotins, absorption spectra of leaf extracts and their significance), carbon dioxide absorption by unilluminated leaves, amylolytic activity of leaves, and the quantum efficiency of photosynthesis.

The most significant contributions from experiments on the reactions of plants transferred to different climates (sea level and elevations of 1,500 and 3,050 metres above the sea) have been, first, "the demonstration of the delicacy of balance between the internal or gene-controlled factors and the external environment ; second, a comprehension of the orderly complexity of species composition in relation to plant distribution ; and third, an evaluation of the capacity of plants to adjust themselves to different environments. The intricate reaction patterns of races of one species to different climates indicate that the capacity for modification is important for the survival and distribution of a given form. The visible effects of the interplay between heredity and environment on plants are complex indeed, and the interpretation of the experimental results demands critical analysis."

Other investigations on experimental taxonomy include regional differentiation into ecotypes and ecospecies, the reaction pattern of ecotypes, equilibrium with the surroundings, chromosome number and environment, etc.

The Desert Laboratory is devoted to the study of a particular environment and its plant life. In past years, considerable work has been done on the role which the broader climatic conditions play in controlling the distribution of plants, but more recently, increasing attention has been given to the detailed differences of climatic and soil conditions which often manifest themselves in a very small area. The tendency has been away from the viewpoint of plant sociology and towards the study of the life history and behaviour of the individual plant. The importance frequently attached "to the social features of plant communities is largely subjective, and indeed somewhat homocentric. The relation of the desert plant to its physical environment is very real and extremely important, and has a far more vital bearing on the interpretation of the vegetation than do its relations to the biotic environment."

The active field work on the Sonoran Desert project has been discontinued, and a study has now begun of living and herbarium material and the collation of data on climate, vegetation, and the distribution of some of the most highly specialized desert plants. The objective of these investigations has been the determination of the origin of desert plants and their differentiation under the impact of the severe environmental conditions of the arid regions.

The research of the Division on ecological problems is being continued by Dr. F. E. Clements and associates; this falls under two chief heads, (1) factor and function in adaptation, and (2) climax, succession, and conservation. As these studies are of fundamental importance in all grassland and conservation research, we take the liberty of quoting this section of the 1937-38 Report in full.

Factor and Function in Adaptation

F. E. Clements, F. L. Long and E. V. Martin

In the early investigations of adaptation by means of the transplant method, it was found that the various environments operated not so much as a complex but rather in terms of a major factor modified in turn by several other factors. Change of altitude in itself did not modify growth rate and stature, but only in those cases where the water relations were significantly different. Alpine dwarfs native at 12,000—14,000 feet on Pikes Peak remained dwarfs in dry situations, whether at the Alpine Laboratory at 8,000 feet, the Plains Garden at 6,000 feet, or near the sea level at Santa Barbara. Likewise, the transfer of tall plants from low to high elevations produced dwarfing in the dry climax areas, but not where moisture was more abundant. Even in the relatively moist spruce forest, alpine species usually remain diminutive, except when the water content of the soil is fairly high.

The explanation of this general behaviour has been found in a series of control experiments with graduated amounts of water and of light. In all of these, stature increased with the percentage of water available, while in the case of light the maximum height occurred at 25 per cent of sunlight and fell off both towards sunshine and towards the lowest intensity of 6 per cent. This is apparently to be explained by the correlation between the tension due to turgor and the amount of growth materials supplied by photosynthesis. With respect to mineral nutrients, the results were somewhat similar; branching was greatest and dry weight highest with the largest dosage of fertilizer, but plants in the intermediate condition were tallest. Temperature has been found to promote woodiness and to increase the life span, but as a rule its specific effects are less definite than with the other three factors, while humidity and wind are chiefly concerned in water relations.

As a consequence of the combined study of factors and functions, the experimental system has steadily assumed more definite form, and the adjustment between nature and control is expressed in four successive stages, namely: (1) native habitats; (2) slight control, chiefly watering during drought periods; (3) moderate control by means of dry and wet gardens, shade tents, lath houses, etc.; (4) practically complete control of water, light, nutrients, soil, length of day, and so forth. In all of these, a

single factor, water, light, or nutrients, has been the chief agent of modification and the others have been equalized in whole or in part. Through many replications by species and seasons, this study has led to more or less definite correlations between factor, growth, and form, reinforced by the measurement of functional response in phytometers. However, it is essential to link together factor and form in a large number of transplant species by means of functional determinations, and this task is now well begun.

Of the three major factors, water has been found to be the most important qualitatively, followed somewhat closely by light, while nutrients are mostly quantitative in effect. Transpiration is measured with much accuracy under field and garden conditions by weighing sealed or free phytometers. The primary difficulty is found in transferring native and experimental plants to containers safely and in growing them from seedlings in phytometer cans. Hence, in the more difficult cases, recourse is had to short-period potometers of shoot and leaf, weighing detached leaves, cobalt paper, etc. These yield approximate values, which can be improved by projecting them against the readings from standard phytometers. In the case of photosynthesis, the method of gas analysis is hardly practicable in the field, and the determination of photosynthate and dry weight yields the best correlation with the various light intensities.

Such direct factors operate immediately upon the vegetative body and their effect upon the reproductive organs is exerted for the most part through the food stream. Marked or extreme dosages are usually reflected in the size, number, or arrangement of flowers, but deep-seated changes in flower or fruit are more readily induced by the manipulation of the food current itself. This is accomplished in a variety of ways, by severe pruning, by excision, by compressing, by injecting glucose, vitamins, poisons, etc., with the result that nearly all species thus treated have shown fundamental alterations in number plan, the regeneration of staminodes and pistillodes, or the reduction or abortion of stamens, pistils, or perianth. The specialization that has produced the social flowers of grasses and composites has provided the most fertile field for both direct and indirect modification. This is not merely because of the longer line of evolutionary steps to be retraced, but especially because the spikelet and head are relatively recent structures, into which vegetative parts such as bracts and scales have been built. Consequently, the glumes and lemmas of grasses and the involucral bracts and chaff of composites respond to water and light much as do their prototypes, the leaves of a shoot.

Although instrumental and phytometer records have been made annually at the Alpine Laboratory for two decades, the study of the process by which functions call forth adaptation has demanded a more complete installation specially fitted to the comprehensive series of fourteen climatic and edaphic gardens. This has been carried out during the past two seasons and continued in part during the current year. For the three climatic gardens, the relative transpiration on the basis of leaf area was 10 at the plains, 6 at the montane, and 4 at the alpine station. At all the gardens, transpiration in the lath houses with 25 per cent light intensity was approximately one-half that in the sun. There was a marked difference between the dry

weights in the sun and in the lath houses at the climatic stations, namely, 100 times greater at the plains, 10 times in the montane, and 4 times at the alpine, the striking reduction with altitude being a response to decreasing temperature. With respect to nutrients, the native gravel soils gave dry weights of 20, 10, and 1 respectively from plains to montane and alpine, while in an imported sandy loam the figures were 100, 33, and 1. This decrease with elevation is partly a matter of water, but largely one of temperature, the seasonal average being 7° C. less at the montane and 20° C. less at the alpine than at the plains.

The five-year intensive study of factors and functions on wandering and stable dunes along the sea-coast at Santa Barbara has been concluded and it is expected that the results will be published during the year. The dune project as a whole not only possesses high intrinsic value as the investigation of a distinctive habitat and its succession, but gains further interest because of certain similarities with alpine situations. The general assumption that the dwarf and procumbent forms of dunes are a response to aerial factors has not been supported by the results, which indicate that soil factors, both water and nutrients, are the primary control. However, the fact that species grown in the series of three different soils in the main garden and on stable and wandering dunes show the highest osmotic concentrations in the latter indicates that air factors are not negligible. Survival is much the lowest in the shifting sand, and only a few species, mostly shrubs, are able to pass successfully through the long dry season. Annuals show a much lower mortality in stable sand, while perennials that persist through the first year usually become permanently established. In some cases at least, this is due to the ability of the roots to follow the retreating water table of the rainy season downward from the 1-foot to the 6-foot permanent level. The general conditions are favourable to the accumulation of woody tissue and a number of annuals have developed into evergreen half-shrubs. This is in accordance with the high survival noted for transplanted shrubs.

With the object of throwing further light upon the fixity of stature and other characters in alpine dwarfs and lowland "talls," reciprocal transplants have been made of a selected group of species each season for a period of three years. During the present season, the transfer of the alpine species was made as soon as they appeared above ground, with the purpose of determining what changes take place during the first summer. Owing to the much later renewal of growth in the alpine zone, lowland plants could not be removed immediately upon emergence, but this was done while they were still short. Care was taken to reduce the shock of transplanting to the minimum and the response of the plants in continuing growth indicated that this had been accomplished. At the same time, the alpine species were also transplanted through a transect of five habitats in the alpine climate, but with varying water contents. Final results will not be available until the end of the growing season, but the initial response of many species indicates that adaptation to the new situation may occur more or less completely during the first year.

Timely rains in the Pikes Peak region have brought forth a larger number of modifications than has been the case in the several dry years that preceded. The majority of the morphological conversions have concerned grasses. *Sporobolus*

airoides has been changed into *S. Wrightii* after two years of excess rainfall in the dunes, and the European *Agropyrum caninum* into *A. subsecundum* by transfer to half-shade. *Trisetum montanum* has been converted to *spicatum* in the sun; *Elymus ambiguus* with 2 spikelets into *condensatus* with 3—4 at a joint under optimum conditions of water and nutrients; and *Bouteloua curtipendula* into *uniflora* as a consequence of renewed blooming in midwinter. Special attention has been paid to methods of modifying the major criteria employed to separate species; thus, the triangular calyx lobes of *Amorpha fruticosa* have been changed to the acuminate ones of *A. californica* by heavy watering. This has also called out dwarf racemes with minutes flowers two to three months before the leaves instead of with them and has produced decumbent rooting stems. Cushion plants typical of the alpine tundra have developed stems and peduncles many times longer than normal, and in some the trailing stems root at the joints. This feature has been called forth in a number of forbs by reduced light or increased water, and the decumbent habit has been induced in a number of perennial grasses. As usual, extreme conditions or manipulation have led to striking changes, as in the number plan of *Ruta*, the ratio of staminate to perfect flowers in *Scandix*, and the production of regular flowers with the conversion of staminode to stamen in *Scrophularia*.

The greater number of the species and many of the genera made use of in the transplant and other experiments in adaptation and origin have not been examined for chromosome numbers. A comprehensive programme in this field has been initiated and it is hoped not only to ascertain the numbers for many of the species concerned but also to discover whether the various methods of manipulation produce any changes in number of chromosomes.

Climax, Succession and Conservation

F. E. Clements and E. S. Clements

The climatic cycle of the past ten years has recapitulated in miniature the much larger cycles of postglacial times and the more remote geological past. This is particularly true of the protracted drought phase with its marked effect upon vegetation and soil, and the human responses that depend upon them. The period has not been sufficiently long for vegetation to exhibit migration on the same large scale as in the past, but local migration, destruction of species populations, changes of composition, and modification of form have all occurred in prairie and plains since the advent of dry years. These have furnished support in dynamic terms to the basic ecological theses that the major communities of the globe and their constituent species are responses to the great climates and that they migrate and evolve as the climates shift during long periods. In other words, each climax, as well as its more recent subdivisions, springs from an earlier vegetation through the further evolution of its dominant species under climatic stress. Hence, the endeavour to reconstruct the phylogeny of climaxes and the climatic pattern of geological periods necessitates retracing the migration and evolution of the species of trees, grasses, and herbs that give each its character. Such results are flowing in increasing measure from the

experimental studies carried on in the transplant gardens, and these serve an additional purpose in disclosing the complex nature of vegetation and the processes that occur in it. Out of these investigations has come the ecological basis for utilizing the vegetative cover as the chief tool in conservation.

To understand the role of cover both as an object of conservation and as the chief method in it, it has been necessary to turn to the life form and life history of the major species, as well as to the dynamic processes concerned in succession. For example, in the mixed prairie of the Great Plains, each important species or dominant possesses its own habit of growth and growth form, exerts its particular reaction upon the soil and upon water, and manifests its own type of competition and co-operation with the associated dominants. They form an organic whole, in which no one part can be changed or removed without affecting all the others, a principle that has served to explain some unexpected results in attempting to modify or restore cover in conservation projects. Succession, both climatic and edaphic, is a universal and inescapable process, and its detailed course must be understood to permit its control or guidance. The general significance of all these features to the restoring of overgrazed pastures and to recovery in abandoned fields has been pointed out in the previous report. During the past year, much attention has been given to methods of supplementing the natural processes by means of furrows and trenches, which promise to shorten greatly the length of time necessary for succession.

The installation of the pasture furrow by the Soil Conservation Service during the past four years has been carried out on such a vast scale, amounting to many thousands of miles, that it has been possible to study its performance in practically all the grassland communities. The results have confirmed the assumptions drawn from the ecological investigations of dynamic processes in each type. In a complete grass cover, the stems and leaves intercept some part of the rain and together with the litter retard movement so that nearly all the water is led into the soil by means of the roots. Under such conditions, the silt and fine organic matter are held in position to maintain the normal soil structure. Cover exerts a similar control of the surface soil by reducing or eliminating the force of wind. These desirable effects are diminished as the cover is impaired by grazing, fire, or drought, and it becomes essential to reinforce the grasses by means of mechanical aids.

The primary question thus becomes one of the size and spacing of the furrow to be employed. Sheet erosion, gullying, and flooding must be prevented, water and nutrients retained and absorbed into the soil, favourable conditions provided for the germination of seed, and the soil disturbed as little as possible, in order to prevent a succession of weeds. Large contour furrows meet these requirements more or less imperfectly, since their chief value lies in holding back heavy rains to prevent accumulation into flood proportions. With spacings of 30 to 100 feet, too much water drains into the ditch and away from the slope where it is needed, carrying with it silt and organic matter. The ditch first becomes a pond, then a mass of colloidal material, and finally a miniature desert with an almost impervious soil, in which seedlings soon perish. The ridge or berm washes into the furrow on one side and over the grass on the other, and this bare area becomes the site of a weedy

growth, of little or no value as forage or protection and barring out grasses by competition for a number of years to come. When wheat grass or buffalo grass is present, a thin band of regeneration may appear at the edges of the ditch and the base of the berm, but this is of little importance by comparison with the width of the drained interval. Furthermore, the amount of surface taken out of production by furrow and ridge may exceed 20 per cent when the interval is 20—30 feet, thus rendering the furrow still less adequate to the needs.

In the task of remedying the defects of large furrows, the experimental plots have been based upon the assumption that the best device will hold practically all the rain where it falls, at the same time preventing washing of the fine surface material. Other desirable effects are to spread the soil so that it serves as fertilizer instead of burying a wide band of cover, to leave roots exposed in the trench to act as channels of absorption, and to prune the roots and thus stimulate their growth. Finally, the shallow trenches catch grass seeds and litter and form excellent seed beds. In the initial tests, the intervals were set at 6, 3, and 1.5 feet, and the trenches were repectively 6 × 4, 4 × 3, and 3 × 2 inches wide and deep. The outcome indicates that the closest spacing produces the best results in accordance with the expectation, and that the larger dimensions are best for the trench, depending in some degree upon soil and condition of cover. It has also been found that much the most rapid recovery occurs when sod grasses are present, and this suggests the desirability of transplanting wheat grass or buffalo grass to treated areas where they are absent. In terms of time, labour, and equipment, trenches or " corrugations " are superior to contour furrows, and in maintaining cover, keeping out weeds, and hastening recovery they possess even greater values.

The study of the relation between cover and wind erosion has disclosed several facts of direct bearing upon the question of the formation of loess deposits. The current view is that the fine material was picked up by the wind during drought in grassland and laid down several hundred miles to the eastward. This theory has been invoked to support the assumption that dust storms have occurred throughout the geological history of the Great Plains and that man in consequence has little responsibility for the recent ones. Through years of field work in the West, dust storms have never been observed to arise from areas with good cover, even during drought periods. Moreover, measurements of the reduction of wind velocity by sparse covers of short-grass render it improbable that dust storms could have come from anything but bare soil. Throughout the " Dust Bowl," the dune ridges have been derived from fields abandoned during drought, and they no longer move when a fair cover is restored. These new facts as to wind erosion and loess deposits were tested in the course of a motor trip to classical loess horizons in Iowa with Dr. Kay and Professor Phillips. As a result, it was agreed that loess had not been derived from grassland but originated from wind erosion on bare glacial outwash plains and valley deposits.

RESEARCH AT THE STATE AGRICULTURAL EXPERIMENT STATIONS

ALABAMA

Two experiments have been conducted over a long period in the Agronomy and Soils Department to determine the effects of legume crops turned into the soil in different cropping systems. The first was started in 1896, and includes plots cropped continuously to cotton with and without winter legumes and also various two- and three-year rotations in which winter legumes were turned for succeeding crops. Legumes increased the yields of seed cotton 560 lb. per acre in the continuous cropping system, 700 lb. in the two-year rotations and 560 lb. in the three-year rotation. In a similar experiment, the effect of mineral fertilizers and of legumes when used separately and in combination in a three-year rotation has been studied.

A study of various rates and times of application of cyanamide on Bermuda grass (*Cynodon dactylon*) lawns has shown that this material may be used effectively in controlling winter weeds ; the substance also provides nitrogen which stimulates the grass in the following summer.

Kudzu vine (*Pueraria thunbergiana*) can be grazed without damage to the stand if proper precautions are taken , the most desirable rate of grazing with beef cattle is about one cow per acre ; the crop is valuable as temporary grazing during July and August. Kudzu is also compared with cowpeas and soybeans as summer green feed for poultry ; although not so palatable as soybeans, it is a satisfactory, inexpensive summer fodder.

Lameness in hogs produced by grazing on Austrian peas (*Pisum arvense*) is studied. It is possible that the condition is similar to lathyrism, caused by eating certain species of *Lathyrus* peas. No previous accounts of such injury from the eating of any members of the *Pisum* genus have been found.

Carotin determinations and biological assays on different varieties of soybeans and cowpeas gave evidence of wide variations in their value as a source of vitamin A.

The department of Botany and Plant Pathology was concerned with the eradication of nutgrass (*Cyperus rotundus* L.) by tillage, cropping or grazing by laying hens ; eradication of *Allium vineale* L. by spraying with 10-90 Creosote-kerosene mixture during January and early February when there are fewest dormant bulbs ; and the *Mycosphaerella* disease of winter peas and diseases of winter peas and vetches caused by *Ascochyta* spp. One of the Entomology studies deals with the life history and control of the cowpea curculio, *Chalcodermus aeneus* Boh.

Two special investigations, dealing respectively with *Crotalaria spectabilis* and *Lespedeza sericea* have also been conducted.

ALASKA

In continuance of the fertilizer tests on rod-square plots of brome grass (*Bromus inermis*), these again showed a profit in the use of nitrate, but little or no gain from

the use of peat, lime, potash or superphosphate. Further plots were laid out on the south slope to study the effect of sodium nitrate in stimulating a second growth of brome grass. The aftermath was cut on September 17 and cured indoors. The treated plots produced 2.1 tons per acre, the untreated 0.33 tons per acre.

Studies of the degree of over-wintering were made by quadrat counts on a mixed stand of timothy, Russian red clover, perennial vetch (*Vicia cracca*), high altitude Grimm alfalfa and white flowered sweet clover (*Melilotus alba*). The field containing these quadrats received hydrated lime on June 5 and was then covered with the rotary hoe, which broke up the hard crust formed by the evaporation of spring moisture, a treatment which was beneficial in creating a surface mulch. All the varieties of forage plants ripened, but since the stand required thickening, none was gathered. Instead, a long chain tied to a pole placed across a pick-up truck was dragged over the meadow to shatter the seed to the ground.

The native grass (*Calamagrostis canadensis*), sown two years before had become established and produced 2,105 lb. of hay per acre. The adjacent brome grass field seeded at the same time yielded at the rate of 1.25 tons per acre. A smaller native grass field, which is becoming established by allowing the natural stand to thicken, produced at the rate of 1,761 lb. per acre. *Equisetum arvense* constituted a fraction of this weight and will probably be crowded out in a few years.

A special report is given of forage crop investigations.

One plot of variegated alfalfa (*Medicago media*), the seed of which came from the high altitudes of Colorado, planted in 1934 and another plot of Ladak alfalfa planted in the same year were both dead from winter killing when investigated in the spring of 1936. Winter rains flooded the ground and an ice sheet formed, which smothered all vegetation on the plots. Ladak alfalfa and alsike clover planted in the spring of 1935 on high well-drained ground came through the winter in excellent condition. One drawback to forage crops such as peas (*Pisum arvense*), vetches, clover and alfalfa is the difficulty in curing. Shocks of peas capped with a small quantity of green oats cured during the rainy season in good condition with no spoilage. Two fields of brome grass were sown during the year 1936, one on a high ridge which is swept by wind in winter and from which the snow is usually blown. Seed was sown broadcast on July 10 and 20. The grass reached a height of 5 to 6 in. before being checked by freezing weather. A poor stand of grass was obtained when drilled with barley early in the spring.

On June 9 and 15 two plots of Russian clover (Viatka No. 15978) were sown with scarified seed. Only a few seeds germinated before the rainy season in July. The plots were badly infested with weeds, but some of the clover germinated early, made excellent growth, reaching a height of 10 to 12 in., and flowered before being checked by freezing temperatures. Seed is to be collected from these plots for further propagation of this hardy forage plant.

Eight varieties of soybeans were sown after inoculation with wet culture ; not more than 40 per cent of the seed treated in this way showed nodule formation. No nodules were developed from dry inoculated seed. The wet-inoculated seed was slow in germinating, but then made rapid growth, branched profusely and grew to a height of 14 to 18 in. before being killed by frost on September 3.

Plants of Arctic sweet clover growing along the roadside and fences seeded heavily. The seed was cut and threshed for further plantings, from which quite leafy growth and excellent quality of dry hay were obtained. A small plot of sugar beet was planted on May 27 on ground which had grown peas in the previous year; the pea crop had been disked into the soil green in the autumn and the ground ploughed in the spring. The beets emerged on June 4, were thinned on June 22, and harvested on September 18. The growth was rapid during the season, the tops reaching a height of 12 to 14 in. The beets weighed 1 to 4 lb. each, and the diameter was from 2 to 4.5 in. The yield was 12.5 tons per acre.

SOUTH CAROLINA

The Chemistry Department is studying the relationship between the carotene content of milk and carotin of pasture grasses upon which the cows have grazed during the summer, and of the feeds used in the barns before the cows are placed on the pasture.

The Dairy Husbandry Department is studying the best methods of production and use of roughage crops for a year-round dairy cattle feeding programme. Experimental work on the value of permanent grasses has been conducted during the summer months, while investigations of the feed values of various types of cured roughages have been made during the winter months. Since the results on the grazing value of Bermuda grass (*Cynodon dactylon*) and carpet grass (*Axonopus compressus*) receiving various fertilizer treatments were published in Bulletin 308, "Permanent pasture studies," the report for 1937 is devoted to a new phase of pasture investigation. Previous work indicated that, under standard management and supplementary barn feeding conditions, Bermuda grass pastures when properly limed and fertilized produced large yields of feed nutrients which are evenly distributed over a grazing season of approximately six and a half months. The present work on pastures is directed towards a determination of the most economic plan of supplementary barn feeding for obtaining the feed values of these pastures with lactating cows.

At the Coast Experiment Station, observations are made on the effect of low-grade basic slag, superphosphate and potash on the growth and composition of *Axonopus compressus*, and on the chemical composition of clippings of the same grass from plots receiving various fertilizer treatments. The beef-producing capacities of Coastal Plains pastures receiving different treatments are being compared.

Forage crops are being studied at the Sandhill Experiment Station. It is stated that it requires about 70 per cent of all the crop acreage of the United States to produce the harvested forage consumed by domestic animals. This forage fed at a rate equal to little more than a maintenance ration will sustain the total number of animals for about six months. The remaining one-half of the feed is supplied by pasturage. Since such conditions exist and the demand is greatly increasing every year, it is necessary that every avenue of approach to the problem of maintaining or increasing the productive power of the soil be investigated, particularly on the

millions of acres of poorer lands which must play a prominent part in supplying the increased production of forage and pasturage required. The forage crop studies at this Station include investigations of *Crotalaria* spp., cowpeas (*Vigna sinensis*), soybeans, velvet beans (*Stizolobium*), kudzu, vetches, winter peas, crop rotations, green manures and cover crops, pasture investigations and tests of new grasses and legumes.

ARIZONA

As a result of earlier work in attempting to find a suitable variety of yellow corn for southern Arizona, most of the introduced Corn Belt varieties have been discarded as being unadapted to local conditions. A few fairly promising introduced hybrid strains were included in 1936, but they were surpassed by the local white Mexican June, and also by the yellow strain produced by crossing Mexican June and Reid Yellow Dent.

Trials with grasses and legumes in nursery plantings have increased interest in the establishment of brome grass, perennial ryegrass (*Lolium perenne*), crested wheat grass (*Agropyron cristatum*) and tall meadow oat (*Arrhenatherum elatius*), as well as dwarf Essex rape.

Test plantings of grasses which appear to have promise for south-western conditions have been extended to include a series of collections of Italian and perennial ryegrass; some strains from Denmark are promising, but no more so than local grown Australian ryegrass. The rapidly growing annual types are promising as winter hay and pasture crops in the southern sections of Arizona; the possibilities extend to the production of seed for local and out-of-State markets. Variety tests have also been carried out with soybeans and grain sorghums.

Detailed work on the factors affecting seed setting in alfalfa was confined to pot studies in order to maintain controlled conditions of moisture in three series; series A was watered in such a manner as to prevent stress, series B was allowed to show a water deficiency, while series C was allowed to suffer considerably between water applications. The number of matured pods has been taken as the measure of the treatment, rather than the seeds produced, due to the fact that the seeds were injured by chalcis flies. A study was also made of the effect of tripping alfalfa blossoms on set of seed pods and preliminary data were obtained on the effect of the variety of alfalfa on seed setting.

Among the animal husbandry studies is one on the nutritional deficiency of Arizona range forages. The plan of the experiment now makes a comparison of limited versus full allowance of cottonseed cake to range cows during dry seasons, as evidence was obtained that mineral salts of calcium and phosphorus did not have beneficial results when fed to cows on a grassland type of range. Supplementary range feeding is also being studied. Bio-analysis tests of the vitamin A content of blue grama grass (*Bouteloua gracilis*) at different stages of growth have been conducted. As cattle fattening rations, mother-sugar-beet silage has been compared with hegari silage as a development of the sugar beet seed industry of the Salt River Valley.

Among the poisonous plants studied by the Botany and Range Ecology Section are species of *Senecio* and *Astragalus*; one of the poisonous principles in the latter plant is thought to be due to soluble selenium compounds taken up by the plants from seleniferous soils. This poisonous principle is also found in species of *Stanleva*.

The botanist is preparing a bulletin on the grasses and sedges of Arizona. A list of thirty of the more valuable grasses has been prepared on the basis of the following characteristics: (1) heavy seed production; (2) good hay production; (3) nutritious forage for winter pasture; (4) nutritious and palatable forage; (5) tolerance to close grazing and trampling; (6) occurrence in abundance over large areas; (7) long seasonal growth; (8) dense growth of basal leaves; (9) pronounced drought resistant qualities; (10) value as a soil conservation plant. The botanist is also preparing, in collaboration with the departments of agronomy and plant pathology, a list of the noxious weeds occurring in cultivated fields in this State.

An effort has been made to obtain a better understanding of the nutrient losses from range soils. Two sets of fertilizer plots were established at the Santa Rita Experimental Range. One set of plots was fenced against cattle, the other left open for grazing. Applications of sodium nitrate, calcium nitrate and ammonium phosphate were made; fertilizer losses through leaching and cropping were followed by weekly soil analyses for nitrates and phosphates. An estimation of the losses due solely to cropping was made by comparing the weekly soil analyses of protected and unprotected plots. Vegetation studies include quadrat studies, plant analysis and osmotic value determinations. Fertilized plots showed an increased palatability, a fact which is supported by a table giving a comparison of feeding analyses of *Bouteloua filiformis*.

Studies were commenced on the effect of cutting, burning and spraying burroweed (*Aplopappus fruticosus*) plants at various seasons. Root excavations were made of burroweed and surrounding grasses to determine the extent to which burroweed competes with grass. Studies were also started on the growth of flower buds and branches in relation to seasonal weather changes and infection by an unknown larva, which destroys the flower buds. Reconnaissance of several areas to note the extent of injury by this larva showed a low percentage of infection, and consequently a limited effect upon seed production.

Permanent quadrats established at the Desert Grassland Station on areas totally protected from grazing, grazed by rodents only and grazed by cattle and rodents, were charted and changes in vegetation were photographed. The influence of climatic factors on range forage production is also being studied. Water requirement measures of several range plants were initiated in 1932 and concluded at the end of the 1936 season. The results of this experiment are available in tabular form.

In a study of the seasonal utilization and forage requirements on range vegetation by rodents, considerable difficulty has been encountered in obtaining and raising jack rabbits and kangaroo rats for the work. No conclusions are yet available.

In the dairy husbandry research, three feeding tests were conducted to discover the feeding value for milk production of hairy Peruvian alfalfa hay cut at bud stage

in comparison with alfalfa grown on the same field, but cut at one-third bloom stage. Feeding tests were also made to test the comparative value of hairy Peruvian and common alfalfa hay ; variety of alfalfa has little effect on feeding value for milk production. Since yields of hairy Peruvian hay are slightly larger, the dairyman is recommended to grow that variety.

In the work on plant breeding, studies with the inbred alfalfa progenies during the summer of 1936 were confined entirely to comparative seed setting among the 224 progenies obtained from selfed seed in 1935. At the present time only alfalfa strain 21-5 is being grown on the Yuma Experiment Farm for seed increase. This permits the collection of seed from individual plants without bagging, thus giving more seed per plant and a more accurate comparison of the seed-setting abilities of the selected plants. The acreage of this strain is also being increased as rapidly as possible at the Station, in order to provide foundation seed for registered seed growing.

ARKANSAS

In the Agronomy Department the fertilizing effects of legumes have been studied. The summer legumes, cowpeas, soybeans, velvet beans, mung beans and *Crotalaria* were grown preceding cotton at the Cotton Branch Research Station. On two series the crops were removed as hay, while on two other series they were ploughed under. Compared on the basis of average returns from both methods of using the legumes, placing highest returns first, the varieties were ranked in the following order : velvet beans, *Crotalaria*, cow peas, mung beans and soybeans. A study has also been made of the residual effect of legumes. For three successive years, bur clover, alfalfa, crimson clover, red clover, yellow trefoil, Austrian field peas, sweet clover and hairy vetch were sown annually as winter cover crops. In 1936, the fourth season of no legumes, no residual effects where the legumes had been removed as hay were shown. Where the legumes had been ploughed under the effects were still in evidence. The highest returns were shown by hairy vetch.

Experiments with corn were concerned with varietal trials, dates of planting, methods of cultivation, and the use of legumes. Varietal trials were made with sorghum for syrup, forage and grain.

The effect of superphosphate on established pastures has been measured by gains of grazing grade beef cattle ; a steady increase in production has occurred. Grazing trials on Bermuda grass pastures showed that pasture fertilized with nitrogen is somewhat superior to that receiving superphosphate.

To date, 143 species of fifty genera are represented in a collection of the grasses native to Arkansas ; 692 different samples have been planted and are being tested for their suitability to edaphic and climatic conditions. Larger adaptability tests on representatives of thirty-one species of the Gramineae have also been established under varying topographic and soil types near the Station. Critical cytological studies have been undertaken to ascertain the chromosome complements of the grass species represented in this collection ; forty-six species have so far been investigated.

The Agronomy Department is also studying erosion of Arkansas soils with particular reference to the extent of soil losses, the influence of soil management practices, the use of lime in fertilizer mixtures and of legumes to provide increased organic content ; variation in productivity and tests of productivity of Ruston fine sandy loam.

In the rice variety and cultural experiments, attention is being devoted to winter cover crops, grass and weed control, irrigation of tilled crops, crop sequences and crop rotation.

A study of metabolism in the cotton plant has been made in sand cultures with a constant flow of nutrient solution, varied as to nitrogen content.

The Horticultural and Forestry Department studies green manures, cover crops and other practices in relation to the production of apples, pears, peaches and other crops.

CALIFORNIA

Soil erosion is active on all the upland cultivated soils of California, particularly in the Coast Range region and in the Sierra foothills. Ample evidence is furnished that "erosion can be prevented or markedly reduced by proper methods of soil conservation." At present there are ten erosion-control demonstration areas in California. Results indicate that in farm lands greater dependence must be placed upon vegetative control methods. In California, the long dry season which promotes early maturity in annuals and drying up of perennials and which is frequently followed by heavy autumn rains before growth is well started, makes it difficult to control erosion through vegetative growth. Low-growing perennial cover crops which will use relatively little water and which will persist through severe dry seasons are required. The wide variety of soil characters and rainfall necessitates the determination of soil erosion methods for each separate region. Unless erosion is checked " the upland farms of California will wear off long before they wear out."

Real forest management over areas wider by far than national forests is vital to the successful solution of the problems of national wild-life restoration, as well as to forest conservation. The establishment of a sound relation between forests and wildlife is essential, and the programme includes maintenance and equilibrium between economic range programmes of farmers, livestock men, and sportsmen. Studies designed to improve the utilization of grass and brush-covered ranges of the foothills are being conducted by the Station in co-operation with the U.S. Forest Service. To the early studies on different intensities of grazing and common grazing systems are now being added biochemical investigations, including the charting of vegetation. Part of this work has been conducted in co-operation with the U.S. Forest Service at the San Joaquin Experimental Range, a cover typical of an extensive valley area ; the results have now been published.

Such great differences have been found in the chemical characteristics of different species of forage plants as to throw some light on their soil preferences, and to account to some extent for the natural grouping of range vegetation. The most important

fact is that isolated biochemical analysis is of questionable value because of the great variation in composition of range plants at different stages of growth. In many localities, particularly where the range is overgrazed or utilized too early in the season, the poison-plant problem has become of local interest.

Studies of the chaparral areas provide data on the rate of growth on burned and unburned areas, germination capacity of the forage plants, period of succulence in the vegetation, moisture content of the soil and nitrifying capacity of the land as a result of burning. Numerous estimates of grazing capacities of soils, before and after burning, have been made. It is extremely difficult to draw general conclusions. On the whole the grazing value of the pure chamise type of forage is extremely low. The type of forage known as chaparral, generally consisting of various species of scrub oak, manzanita (*Arctostaphylos*) and *Ceanothus*, furnishes a somewhat better forage than the pure chamise, but is inferior for utilization by livestock.

In California, as well as throughout the West, the practice of burning the range dates back to Indian customs. The problem is still controversial, and requires a large amount of additional research before a satisfactory solution can be found.

The California Agricultural Experiment Station is conducting many tests with forage legumes to determine their adaptability. For pasture and hay a mixture of vetch and oats is gaining popularity where alfalfa cannot be produced profitably because of damage from wilt or for other reasons. Cultural recommendations for soil-building crops can now be made. The types of vetch include purple, common, and calcarata. For summer forage or green manure crops two varieties of cowpeas (*Vigna sinensis*), Iron and Brabham, are increasing in popularity; these have a high yield and are resistant to nematodes. Selections of pure-line strains of each variety developed by the College of Agriculture are now being distributed to farmers under the California Approved Seed Plan.

The dolichos bean (*Dolichos lablab*) is a valuable summer legume, suitable for cover crops and to some extent for forage, especially in the interior valley where the average temperatures are rather high. The Station has been experimenting with a pure strain called K677. Guar (*Cyamopsis tetragonoloba*) is successful under continuous high temperature and with ample irrigation; seeds of two strains developed by the College are being produced for distribution at the Imperial Valley Field Station, and at the University Farm, Davis. Another favourite soil-building crop, especially in orchards, is *Melilotus indica*; a complaint that this crop does not mature early enough will be overcome by the use of an earlier (10 to 14 days) and more rapidly growing (8 to 12 ins. more growth) strain now being distributed for trial.

In many sections of the State, alfalfa is badly attacked by disease, especially wilt. The Station, in co-operation with the Division of Forage Crops and Diseases of the U.S. Department of Agriculture, has been trying to develop wilt-resistant strains. Of the fifty-nine varieties and strains tested, more than half showed no resistance while the remainder varied from 0.45 to 26 per cent. The second generation, however, has a much higher resistance than that possessed by the parent stocks; as the resistant strains are extremely variable in growth habit, the outlook for the development of satisfactory wilt-resisting species for Californian conditions is encouraging.

During the year under review, the U.S. Department of Agriculture initiated for the first time weed research studies on a national scale, and weed control is now taking a recognized place with crop rotation, fertilization, flood control, and soil erosion in the general conservation programme. In the study of chemical weed killers, a co-operative project is being established at the branch of the College of Agriculture at Davis; the object of this work is chemical weed control. Experiments include the relation between soil type and availability of sodium chlorate and sodium arsenite, relative toxicity of weed killers in the principal agricultural soil types of the State, relative susceptibility of important weed species and common herbicides, toxic properties of untried chemicals, poisonous effects of arsenic, chlorate, and borax, and factors affecting borate and chlorate toxicity. Two years of investigation of Klamath weed (*Hypericum perforatum*) have demonstrated that sodium arsenate is the most effective chemical for control.

CONNECTICUT

The Department of Agronomy devotes much attention to the maintenance and improvement of pastures. The effects of fertilizer treatments on the soil, the flora and production have been measured by grazing for sixteen years. Fertilizers were first applied in 1924. Based on the maintenance and gains in weight of heifers during the past four years, the total and seasonal productions of plots fertilized in various ways have been as follows :

Fertilization	Relative total production	Per cent of total production before June 15
None	100	44
LK	132	45
P	170	45
PK	198	42
PL	217	48
PLK	219	48
PKN1	284	54
PKN2	255	37
PKN3	230	43
PLKNN1	318	63
PLKN12	353	55
PLKN123	325	49
PLKN23	302	46

P = superphosphate (16 per cent) at 2,000 lb. per acre since 1924.
K = muriate of potash at 400 lb. per acre since 1924.
L = limestone at 4,000 lb. per acre since 1924.
N1 = nitrogen at 28 lb. annually in April.
NN1 = nitrogen at 56 lb. annually in April.
N2 = nitrogen at 28 lb. annually in June.
N3 = nitrogen at 28 lb. annually in August.

Without adding any seed, remarkable changes in the botanical composition of the sward have been produced by the fertilizers. For example, the percentages of area occupied by *Poa pratensis* vary from 1 to 80; by *T. repens* from 0.2 to 19; by *Danthonia spicata* from 0 to 24; and by weeds of all kinds from 3 to 50.

On a tilled field with a phosphorus deficient soil the yields of three different seedings of pasture species have been consistently larger where the superphosphate was mixed with the upper two inches or upper four inches of soil, than where it was applied on the surface. However, in the case of the Kentucky bluegrass (*Poa pratensis*), Rhode Island bent (*Agrostis tenuis*) and white clover seeding, only a 5 per cent increase in yield resulted from mixing the superphosphate with the soil. The placing of potash was not important. During the previous four years Kentucky bluegrass and Rhode Island bent in pure culture have been cut with a lawn mower and the yields of dry matter determined. The peak of production of both grasses has been changed from June to July or September by withholding April nitrogen and adding sulphate of ammonia and nitrate of soda (56 lb. N per acre) in June or August. August nitrogen decreased the response to April nitrogen, but April nitrogen did not decrease the response to June or August nitrogen. White clover was least prevalent where nitrogen was applied three times per season; if added only once, a June application was the most effective in retarding the spread of white clover. Total yields have been nearly as large under PK fertilization as with three applications of N per season; this may be due to the large amount of white clover (38 per cent of the area) on the mineral plots.

The results from 1930 through 1935 on a study of the adaptability of varieties and species of grasses and clovers for Connecticut pastures have been published in Bulletin 208. Outstanding species have been: alfalfa (*Medicago sativa*) under favourable soil conditions; Ladino clover (*Trifolium repens*) as a perennial legume to include in mixtures containing one or more grasses for widely varying soil conditions; medium red clover (*Trifolium pratense*) for two-year leys; orchard grass (*Dactylis glomerata*) and timothy (*Phleum pratense*) for rapid establishment, good stands and large yields for 4 to 5 year periods. Legumes have furnished a much larger proportion of their total yields after July 1 as compared with grasses, a fact which has been apparent also in legume-grass mixtures.

In a study of the causes of fluctuations in the prevalence of white clover, many compounds, not commonly included in fertilizers, have been used on three varieties seeded on different soils. No particular response to the various treatments has been detected. On a field depleted in fertility by long continued removal of hay, white clover is much more prevalent where either manure or potash was applied in addition to limestone and superphosphate.

The Departments of Dairy Industry, Agricultural Engineering, Agronomy and Bacteriology are co-operating in a study on artificial drying of hay, with special reference to hay chopped into storage. A detailed report of the success achieved in the rapid removal of the moisture content from hay is given. From a study of the carotin content it was found that the leaves of fresh, immature alfalfa plants contain 99.82 per cent of the carotin in the entire plant. The percentage loss of carotin in hay dried

on the field in different ways is given. In connexion with the storage of chopped alfalfa in silos new data were obtained on the rate of destruction of carotin in stored hay. From 86 to 95 per cent of the original carotin was destroyed during the first two weeks of storage in a silo in which the temperature reached 180°F. and from 98 to 99 per cent had been lost at the end of four months. Since the hay in these silos attained a rather high temperature and developed a much darker colour than that placed in ordinary storage, it is probable that carotin is more stable under ordinary storage conditions than these figures would indicate.

DELAWARE

A study of soil conservation practices was conducted through the co-operation of the Departments of Agricultural Economics, Agronomy and Chemistry, and the U.S. Agricultural Adjustment Administration. The purpose was to determine the conservation practices within the different types of farming in Delaware in order to establish a basis for more accurately adjusting benefit payments to co-operative farmers. Areas were selected typical of the three major types, namely, truck crops, tree fruits and general farming. Data are being collected on: cropping systems, management of cover crops and green manures, management of pastures, amounts of livestock, rates of application of farmyard manure, kinds and rates of applications of fertilizers and lime, and rates of seeding different crops. From a survey of the extent of soil erosion, it would appear that in most cases erosion can be controlled by adjustments in the cropping system.

Results over a period of 28 years, 1908-1936, have been obtained from fertility rotation experiments. The crops were grown in a rotation of (1) corn followed by a cover crop of rye and vetch or crimson clover, (2) oats or soybeans, (3) wheat, (4) timothy and clover. These crops received many different fertilizer treatments with and without lime. They received about twice as much fertilizer during the first half of the period as during the second half.

A study of pasture improvement is the outcome of early investigations in south Delaware; a forage which would provide pasture in mid-summer is desirable. It was thought that an improved strain of Korean lespedeza (*Lespedeza stipulacea*) might improve the pasture; seed from south Carolina and Kentucky gave the highest yields for a three-year period. Three thousand pure line selections were made from the early introductions and 300 retained for further trials. These were grown in ten-feet rows for further observation and seed production; they have a spread of from 12 to 33 inches and each selection is very uniform within the row, indicating that a pure line has been isolated. These selections will be tested in small broadcast plots and rows as well as in grazing trials.

FLORIDA

Pasture research has involved various fertilizer treatments and their effect on yield and composition, methods of sampling pastures to obtain comparable yields

of herbage, comparison of burnt and unburnt native pastures, the effect of land preparation previous to seeding on establishing and maintaining pastures, and the botanical composition of native pastures burnt and unburnt and changes in pasture flora under the two conditions. Other research includes the value of centipede grass (*Eremochloa ophiuroides*) pastures as affected by soil characteristics and other factors, crop rotation studies with corn, cotton, *Crotalaria* and Austrian peas; the value of *Crotalaria* species as green manure, crop adaptation studies (including *Pennisetum purpureum* and *Cajanus indicus*), fertilization of pasture and forage grasses (see Bulletin 269), fertilization of Napier grass (see Bulletin 215), effects of various rates of nitrogen fertilization from different sources of nitrogen on Bahia grass (*Paspalum notatum*). The project on date of seeding and phosphate requirements of winter legumes and their effect upon subsequent crops has been closed, and a manuscript is being prepared.

A study of *Crotalaria* as a forage crop is in progress in co-operation with the Division of Forage Crops and Diseases, Bureau of Plant Industry, U.S. Department of Agriculture; this study included variations on rate of seeding *Crotalaria intermedia*.

Another pasture study is that on the development and deterioration of roots in relation to the growth of pasture plants grown under different fertilizer and cutting treatments. Work on a new project on the composition factors affecting the value of sugar cane for forage and other purposes has begun, as well as a more intensive study of growth behaviour, composition and metabolism of Cayana sugar cane.

Among the miscellaneous agronomical experiments may be mentioned those on ensilage of sugar cane in a stack silo, and a comparison of production of different silage crops (Napier grass, Cayana sugar cane, sorghum and corn, followed by cattail millet) grown at relatively high fertility levels.

In the Animal Husbandry Department the ensilability of forage crops and feeding value of plants such as *Crotalaria*, pea nuts, sweet potatoes, corn, etc. have been studied; also the toxicity of *Crotalaria* to livestock.

The Chemistry and Soils Department is concerned with determination of the effect of green manures (*Crotalaria* spp.) on composition of soil, chlorosis in corn plants and other field crops (see Bulletin 292 for effect of zinc sulphate on field crops).

GEORGIA

The Departments of Agronomy and Animal Industry present a special report on pasture investigations. The advent of the cotton boll weevil, low prices for cotton and other farm products, low fertility due to erosion, and other factors have caused abandonment of large areas of previously cultivated land in this State. Considerable interest in livestock production has recently developed and the Experiment Station has been called upon to determine the feasibility of converting this abandoned land into profitable pastures. An intensive study of various pasture plants and their adaptability to various soils has commenced in co-operation with the Tennessee Valley Authority, the United States Department of Agriculture, the Coastal Plain Experiment Station and other State institutions.

The limiting factors in pasture productivity are being studied on a series of plots in which Bermuda grass (*Cynodon dactylon*) and common lespedeza (*Lespedeza striata*) furnish the summer clippings, and white Dutch clover the winter and spring clippings. Various quantities and combinations of nitrogen, phosphorus and potash are applied with and without limestone, and with and without added water. A special sprinkling system has been constructed in order that the watered plots may be given definite amounts of water whenever natural rainfall becomes the limiting factor. In co-operation with the U.S. Department of Agriculture, a study is being made of the effect of various rates of phosphate applications, with and without limestone, on the establishment and survival of some important clovers under grazing conditions. The relative value of nine important phosphatic fertilizers is being determined on plots on which winter legumes are to be established. The most productive and economical source of nitrogen will be determined on a series of Bermuda grass plots. Nitrogen, supplied to the grass indirectly through the use of phosphate, lime and potash, to allow the growing of winter clovers on some plots, is an essential part of the study of the economy and effectiveness of nitrogen sources for Bermuda grass.

Analysis of the more important pasture species will be made for minerals, crude protein and crude fibre, and the effect of fertilizers in producing changes in chemical composition will also be determined.

The eradication of bitterweeds (*Helenium tenuifolium*) and broom sedge grass (*Andropogon virginicus*) is being attempted by increasing soil fertility, seeding desirable species, and cutting.

Selected strains of pasture plants are being compared with commercial strains. Seeds and seedlings of the more important pasture plants have been given colchicine treatments in attempts to induce greater genetic variability in these species and it is hoped that by selection new and valuable strains will be produced. It was found that the seeds of some plants were easily killed by colchicine treatments, but that subsequent treatments of the seeds with plant hormones allowed more drastic colchicine treatments and still enabled the seeds to survive.

Changes in soil temperature and moisture from season to season throughout the year are important factors in the production and distribution of the various pasture plants. These factors may be relatively more important on upland than on lowland pastures. Preliminary data have been obtained illustrating the extreme environment on upland pastures and the difference between distinctly lowland and upland pastures.

Various " winter " legumes and grasses have been established on small plots on Bermuda grass sod on upland pastures to determine their adaptability to the Piedmont section of Georgia for winter and spring pastures. It has already been noticed that all the winter legumes grown have a stimulating effect on the growth of Bermuda grass. It thus appears possible to supply nitrogen indirectly to summer grasses by establishing winter legumes with the use of phosphate. The growth of these winter clovers, however, practically eliminates the lespedeza from the Bermuda-lespedeza pasture and thus greatly changes the quantity and quality of the summer forage. The winter clovers used were white (*Trifolium repens*), Persian (*T. resupinatum*), hop (*T. procumbens* and *T. dubium*), cluster (*T. glomeratum*), crimson (*T. incarnatum*), and bur (*Medicago arabica*).

The Entomology Department is concerned with the cowpea curculio (*Chalcodermus aeneus*).

The Horticultural Department has planted a ten-acre peach orchard with various cover crops, in order to determine the feasibility of using permanent and annual cover crops in orchard practice. Plot treatments include (1) permanent or semi-permanent alfalfa, (2) winter cover, vetch and Austrian winter peas alternating, (3) winter cover, vetch and Austrian winter peas alternating, and a summer cover of cowpeas, and (4) clean cultivation.

At the branch experiment station in the Coastal Plains, at Tifton, Georgia, considerable work is in progress on the breeding of grasses and forage plants. (See Report of Division of Forage Crops and Diseases, p. 17.)

HAWAII

The Agronomy Department's report on pasture investigations includes details of the vegetation survey of Hawaiian ranges. A plant survey of the principal ranches, to list all species of grasses, legumes, and miscellaneous plants of economic importance to the range industry, was completed during the year. The different types of plant associations were mapped and the principal pasture areas classified. The herbarium now contains 150 grasses, twenty-five legumes, and 200 miscellaneous plants found on Hawaiian pastures. The most important of these are being described and illustrated for ultimate publication. Data obtained from ranchers as to management, value or place in the grazing scheme, grass introductions, and relative merits of different species are being analysed and combined with the plant survey to form a useful basis for classification of ranches as to type and for mapping of plant associations as they are determined by ecological factors and ranch management.

Many new species of pasture plants have been added to the Station nursery and branch nurseries, studies of adaptation, growth habits and persistence being conducted over a considerable altitude range. Examples of this zonation in the successful introduction of new species are *Bromus catharticus, Poa pratensis, Holcus lanatus, Trifolium repens,* and *Lolium* species, which grow well above 2,500 ft.; *Cajanus cajan, Panicum purpurescens,* and *Prosopis chilensis* are important pasture plants only at lower levels.

From tests in the co-operative grass gardens a number of recently introduced species not yet established on the ranges are showing great promise of future usefulness to Hawaiian ranches and dairies. The most important are representatives of the genera *Cynodon, Digitaria, Panicum, Andropogon,* and *Bouteloua,* as well as species of *Hilaria, Ischaemum* and *Themeda,* while of previous introductions *Melinis minutiflora, Chloris gayana,* and *Pennisetum clandestinum* are showing great adaptability, thriving as well in wet as in dry locations.

In the trials on fodder crops, eight seedling strains resulting from open pollination of Napier grass (*Pennisetum purpureum*) and crosses of Napier and Merker (*Pennisetum Merkeri*) grasses are being compared for yield with the standard Napier grass. The frequency of cutting of Napier grass is being correlated in another experiment

with yield, persistence of stand and nutrient content. The greatest green forage yield of palatable portions was obtained in the 6 weeks' treatment and the smallest in the 14 weeks' treatment. Results indicate that 8 to 10 weeks constitute the most desirable interval between cuttings, this period being long enough to produce sturdy, long-lived stools with the highest total yield of palatable forage.

Tests were started in 1935 to determine the best conditions for storage of crop seeds under humid tropical and sub-tropical conditions, such as exist in Hawaii. Results are presented, in tabular form, of germination tests after 18 months of storage under various relative humidity conditions at room temperatures averaging 75°F. Control of humidity is a vital factor in seed storage at temperatures existing in Hawaii, which average about 75°F. The drop in percentage of germination when stored at 75 instead of 60 per cent humidity is very sharp for most kinds of seed. The difference between species is quite evident. Soybeans did not germinate well after storage at a low relative humidity, rice required about 45 per cent humidity for satisfactory storage, while corn and alfalfa were the most tolerant of the seeds tested. Lower percentages of germination in the air-tight control illustrate the need for air circulation in the storage of certain seeds.

The effect of temperature on seed storage is also being studied ; results indicate that a relative humidity of 45 to 60 per cent is best for storage at temperature of 75°F., but if the temperature can be reduced to 60° F., or below, no humidity control is necessary. These tests are being continued to determine the interaction of time, humidity and temperature.

Methods of accelerating the rate of germination of the hard-coated seed of *Leucaena glauca* have been studied. Without treatment, only 8 per cent of the seeds germinated during a 2 months' period under standard conditions of temperature and humidity. Pre-treatment of seed with hot water or sulphuric acid would appear to be practical for inducing quick germination, thus permitting the plant to take advantage of the full growing season.

Growth, flower bud formation, fruit setting and fruit development are intimately related to, and governed largely by, nitrogen and carbohydrate metabolism. In Hawaii, rainfall, which affects soil fertility and soil nitrogen, and light, which affects carbohydrate synthesis, vary tremendously in different localities. With the uniformly favourable growth temperatures existing throughout the year, the problem of developing a carbohydrate/nitrogen relationship in the plant favourable to flower differentiation, and at the most desirable season of the year, becomes of extreme importance. Certain of the tropical plants do not enter a rest period, but make a flush and vegetative growth at any season, depending upon the nitrogen and water supply, thus utilizing any accumulated carbohydrate reserves. Their blossoming is often sporadic and uncertain. A series of investigations has been initiated to determine whether the carbohydrate/nitrogen balance may be affected by culture, fertilizer, pruning, or irrigation.

Several forage crops are being tested on the dairy herd by the Animal Husbandry Department ; these trials include sesame meal versus soybean oil cake meal, the addition of cane molasses to roughage, the value of algaroba bean (*Prosopis chilensis*)

meal, and comparison of green Sudan grass with green *Panicum* grass. Tests with beef cattle include comparison of pastures of *Leucaena glauca* with and without a supplement of cane molasses, grass versus pigeon pea (*Cajanus cajan*) pastures, and value of supplementary cane molasses and protein supplements in pen feeding of steers with Hawaiian by-products.

IDAHO

Studies have been made on pasture grasses under grazing conditions by the Department of Agricultural Chemistry. Carotin varies considerably; the content corresponds with former analyses, except in *Poa pratensis*, which is high in carotin, but low in vitamin A potency. There also seems to be a direct correlation between carotin content and protein content. The stability of carotin is very low under normal farm methods; rapid drying methods have been developed to produce a product high in vitamin A.

The Agronomy Department reports on forage breeding. Sweet clover, alfalfa, red clover, Ladino clover, peas, grasses, sunflower and corn are the principal crops being investigated. A pink-flowered brown-seeded Ladino clover, two weeks earlier and more winter hardy than the original strain, has been developed. Breeding for improvement of white blossom sweet clover and the production of a yellow blossom purple-seeded type has been continued. Several valuable types have appeared among the white blossom selections; one type sets all its seed within a 10-day period, one has fine leafy stems, and another branched root systems. The yellow blossom purple-seeded types are still segregating for seed and plant characters, but it is expected that a variety of this type with an alfalfa-like crown may be developed.

A new strain of slender wheatgrass has been tested for forage and seed production. Many crosses were made on Alaska and Idabell peas in an attempt to produce a more uniform deeper-green pigment in the pea seed. A more uniform yellow-seeded strain is also desired.

Eight strains of Turkestan alfalfa furnished by H. L. Westover, U.S. Department of Agriculture, have been tested over a three-year period; the better strains of Turkestan yield at least as well as Grimm.

Extensive varietal tests of field and garden peas have been conducted. Comparative yields were obtained on peas in alternate wheat-pea rotation and in an alfalfa-wheat-pea rotation. Pea yields were increased by the introduction of alfalfa in the rotation; sweet clover should produce similar results.

The Station has continued to co-operate with the Bureau of Entomology and Plant Quarantine in wireworm infestations; the growing of yellow sweet clover may be associated with marked increases in these. A rapid increase of wireworm populations in red clover soil is apparently not due to any special attractiveness which that crop has for ovipositing beetles. Wireworm populations may reach a low point of one per square foot, or less even when no intentional control is applied. Factors governing cycle of infestations are not fully understood. Allowing a four-year old stand of alfalfa to remain unirrigated for a season resulted in a 60 per cent decrease

in wireworm population. Fallow soil areas under cage conditions apparently attracted more egg-laying females than soil areas in which crops were growing. Eight acres of land were kept flooded for eight days, resulting in a 56 per cent decrease in the wireworm population. During that time the average temperature of the upper six inch layer of soil was 72.4°F.

According to the Department of Plant Pathology, losses from alfalfa wilt were less severe. It is evident that wilt is most destructive following severe winter injury. New varieties and selections are being developed. A widespread disease of alfalfa called "black stem" (*Phoma medicaginis*) has been studied and a preliminary report submitted for publication. The perfect stage of the fungus is *Pleospora rehmiana*. The knowledge of the complete life cycle of the organism causing black stem will be of value in formulating control measures.

ILLINOIS

The research of interest falls under the headings of Soils and Crops, Livestock Investigations, Dairy Cattle and Products, and Entomology Investigations. The different items will be noted in order of their occurrence in the Report.

Possibilities of substantial returns to the farmer who uses soil conserving and building practices are emphasized in results of studies conducted at the Station for the past 25 years or more. Cultivation, crop rotation and soil treatment all figure in land use policies and in soil conservation. On the Morrow Plots, established in 1876, rotation ranks first of these three factors. When the various combinations of two factors are compared with the cultivation factor, increases ranging from 32 to 119 per cent are obtained. In these combinations only those containing red clover in the rotation produced increases of more than 100 per cent. The highest yields of corn are obtained when all three factors are combined. They were more than doubled in the two-year rotation without the legume, and nearly trebled in the three-year rotation with the legume.

The repeated growing of sweet clover with the accompanying increase of other crops removes large amounts of potassium from the soil. Where available potassium is present naturally in limited amounts, increased crop yields can be secured only by supplying potassium in the form of straw, manure or potash fertilizers.

One evidence of crop adjustment and the trend to more pastures and forage in Illinois is the fact that between 1931 and 1935 the acreage of alfalfa was almost doubled. A further steady increase is expected. Wilt and winter injury seriously affect alfalfa production and further extension of the acreage will depend upon locating resistant varieties. A two-year record for the ten leading types was made by a yield per acre varying from 3.41 to 3.68 tons (the three highest being Hardigan No. 19910—3.68 tons; Ladak No. 20190—3.66 tons; Hardigan No. 18999—3.65 tons.)

In a study of soybeans as a green manure crop, best results are obtained when the entire crop is ploughed under, provided that erosion is avoided. A spring crop is usually more satisfactory than a crop sown in the autumn immediately after the soy-

bean crop has been harvested. When wheat follows soybeans the yields are usually improved by phosphate fertilization. The tops of the soybeans constitute about 90 per cent of the plant. Consequently, even well-nodulated soybeans add little or no nitrogen to the soil when the seed crop is sold, even if the straw is returned to the land. Considerable amounts of phosphorus and potassium are removed in the seed. Obviously the soil-improving value of soybeans is limited where the crop is removed.

Hay-type soybean varieties have been compared with seed-type varieties produced for hay and seed at Urbana. The average yield of the former over a six-year period was 2.99 tons of hay, and 24.4 bushels of beans per acre, while the average yield of the seed-type varieties was 3.02 tons of hay and 30.4 bushels of seed.

A study is being made of the inoculation of legumes. The Illini soybean is easily nodulated, whereas the Peking has few nodules. The resistance, as well as the susceptibility, to infection by nodule bacteria is an inherited character. Annual lespedezas also differ in ease of nodulation. Frequently Korean lespedeza shows good nodulation under conditions where Common lespedeza shows few or no nodules. The difference in susceptibility again appears to be genetical.

The acreage devoted to legumes in Illinois would be considerably larger if red clover could be depended upon to produce a crop more regularly. At present less than half the seedlings yield a crop, but the number of failures can be reduced if certain practices are followed. Important points are the type, rate and method of seeding the nurse crop. Best stands of clover may be obtained by seeding in barley. Early seeding in winter grain is superior to late seeding. No advantage is obtained from drilling in winter grain as compared with broadcasting. Hay and seed yields of red clover are usually increased materially by autumn cutting of first year clover.

The seed coat of much of the seven to nine million acres of corn (maize) that are planted every year in Illinois is injured at the crown, with resulting heavy losses in the vicinity of 27 per cent lower yield.

Seed-corn disinfectants have been proving their value by increasing the yields of early planted corn by an average of 3 to 5 per cent over a period of years. Greater stabilization of the Illinois corn crop appears likely as a result of the use of hybrid varieties. It is estimated that only hybrid seed was produced in Illinois in 1935 to plant 200,000 acres, and that only foundation hybrids were planted in the following spring to produce seed for at least a million acres, provided a normal yield was obtained. Hybrid corns vary widely in yields and adaptation. The resistance of corn hybrids is related to carbohydrates.

Studies have been continued on the storage and shrinkage of crops of alfalfa and soybean hay in order that storage methods may be improved. Figures have been obtained of the changes in weight of hay stored loose or baled.

With the present trend towards the wider use of soil-conserving crops, studies started several years ago by the Experimental Station to work out the best combinations of forage plants and to study new pasture and hay crops have taken on added importance. The development of better types of grasses is also in progress, as well as studies to determine the variation in growth and in the type of different plants. Special attention has been given to Kentucky bluegrass (*Poa pratensis*) and redtop

(*Agrostis* spp.). In a preliminary study of 400 single plants of each of these types of grasses, wide differences were found in the width of leaf, erectness and compactness of growth, rate of spread in the formation of a sod, and in resistance to leaf rust and mildew. About forty plants of each species were subdivided into twenty-five sections, which were then planted 40 inches apart each way upon an area a rod square. The growth and behaviour of these plantings are being observed and the better types will provide seed for future plantings. Some plants were enclosed in muslin bags to produce self-fertilized seeds. Kentucky bluegrass produced selfed seed more readily than redtop. Little difference was noticed in the types of plants produced from the self- and open-pollinated seed of single plants of the Kentucky bluegrass. Seedlings of a single plant were alike, while seedlings of different plants showed variation. On the other hand, seedlings from selfed seed from redtop plants were as variable as seedlings from open-pollinated seed. It is suggested that Kentucky bluegrass is either a self-fertilized crop, or reproduces in such a manner that the resulting seedlings resemble the parent very closely, but that redtop is cross-fertilized.

Work on the eradication of weeds by chlorates has persisted on a number of different weed species. Weeds have become so numerous and destructive that they now rank with soil erosion, diseases and insects as a farm menace. Garlic and wild onions alone in 1930 were estimated to have caused damage of $300,000 to Illinois wheat, and of about $2,000,000 to Indiana wheat. More recently field bindweed has become a serious threat. Cultural and chemical methods of control, as well as other physiological aspects of the problem are being studied as means towards the eradication and control of bindweed and other species. A complete classified bibliography on all material pertaining to weeds is nearly complete. In bindweed control three chemicals have been found to be more lethal than any of the others tried, namely, sodium chlorate, calcium chlorate and sodium thiocyanate. It will probably be necessary to make three or four applications of the chemical before the bindweed is eradicated.

Among the livestock investigations a report is given of a study of the use of pastures in fattening beef calves. The belief that winter pasture makes possible a saving in the amount of grain required to fatten a calf was not confirmed by results. Further investigations are necessary to determine the best method for utilizing blue grass pasture in the production of baby beef.

Information on the relative value of some of the newer pasture forages for beef cattle has been obtained, the pastures being sweet clover, alfalfa and brome grass. Alfalfa proved to be much superior.

Although lespedeza and soybean hays are relatively new crops in Illinois they already are produced more extensively than red clover or alfalfa in the southern half of the State. Considerable need has, therefore, arisen for more information concerning their feeding value for beef cattle. No significant differences have yet been observed between the two types of hay.

Soybeans are much poorer in vitamin A than yellow corn (maize), a fact of importance in evaluating the beans as a food for man and livestock.

Millions of tons of silage are used in feeding the 1,372,000 milk cows and heifers

in the State, but the question of the best corns to use for this purpose is doubtful because of the recent development and wide use of many hybrids. Sixteen hybrid corns have been compared for this purpose; carefully selected corn hybrids, such as those used in the test gave large yields per acre, and produced a silage having a high feeding value per ton. Legumes were also studied for their value as silage. Rainy weather frequently causes great losses during the curing of hay, particularly with first-cut alfalfa and late-cut soybean hay. It would appear that alfalfa harvested at an early haying stage and ensiled directly from the field without wilting is likely to make good silage, although better keeping qualities are assured through the addition of not less than three per cent of molasses, or 60 lb. per ton of alfalfa.

Illinois is the fifth American State as regards milk production; it already has more than 7.5 million acres of pastures, but new pastures are being started and old ones improved under the stimulus of soil conservation measures. Pasture improvement is, therefore, an important aspect of the Station's work. One phase deals with the improvement of an old bluegrass pasture, another with a combination of crops which will provide pasture over a number of months, for example, winter rye, bluegrass, alfalfa, Korean lespedeza and Sudan grass. The third series has been planted to alfalfa to compare the crop as used for pasture, hay or soiling. Results indicate that high-producing dairy cows which receive all or a large part of the roughage from pasture do not remain in as good a state of flesh and are harder to keep at a high level of production than those which are barn-fed.

IOWA

Among the Committees of the Station are included the following:

PASTURE IMPROVEMENT: to integrate and enlarge the research programme of the Station on pasture improvement and to co-operate in regional programmes on pasture research.

SILAGE STUDIES: to develop plans for research work on the general topic of the development of methods for preparing satisfactory silage from such legumes as alfalfa, clover and soybeans.

DISTRIBUTION OF SEED AND PLANT MATERIALS: The Station originates many new varieties of plants. Some are disease-resistant, others well adapted to Iowa conditions. Many questions arise as to the fair distribution of this stock. It is the work of this committee to consider the general Station aspects of the problem of seed and plant distribution and to set up adequate rules.

STATE SOIL CONSERVATION ADVISORY COMMITTEE: to integrate extension teaching, field programme and all research in Iowa as these relate to soil conservation and land use planning and to review proposed projects.

FLOOD CONTROL AREAS AND PROBLEMS IN IOWA: to make recommendations as to areas in Iowa which might properly be listed with those areas which are included in the Omnibus Flood Control Act of 1936.

FLOOD CONTROL IN IOWA: A joint committee representing the Agricultural Experiment Station and the Agricultural Extension Service, which co-operates with the flood control co-ordinating committee of the U. S. Department of Agriculture.

STUDIES ON THE CHEMICAL COMPOSITION OF FARM CROPS: to co-operate with the U. S. Department of Agriculture in a study of the chemical composition of leading agricultural crops of Iowa as influenced by variety of crop, type of soil, kind of fertilizer, cultivation, weather and other influential factors.

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A considerable amount of work is in progress in co-operation with the Bureau of Plant Industry, on crops such as clovers, alfalfa, soybeans and other forage plants. The objects are to test or study:

(1) The comparative value of different regional strains of red and sweet clover, development of improved and more hardy strains, seed and forage production, and the factors affecting clover seed production.

(2) The comparative value of varieties and strains of alfalfa from different parts of the United States, special attention being given to winter killing.

(3) Selections and new introductions of soybeans from the standpoint of improved varieties for forage, silage, pasture and oil production.

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Weed control methods are being investigated, particularly on European bindweed (*Convolvulus arvensis*) by a study of (1) the biology of noxious weeds, (2) physiology of weeds, (3) herbicides, (4) cultural practices, and (5) methods of dissemination and establishment of weeds.

Agronomical, physiological and genetical research with soybeans is directed towards a varietal test to determine the effect of soil and other environmental influences on yield and composition and the development through breeding and selection of superior varieties for industrial and other uses.

Investigations are in progress in co-operation with the Soil Conservation Service on the establishment, reseeding or improvement of pastures. Various other erosion aspects are being studied and an experimental regional erosion-control nursery has been established at Ames.

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Forage crop problems are being studied by the Farm Crops Sub-section of the Iowa Station.

The value of medium red clover, Hubam clover, and biennial white sweet clover as green manure crops has been compared. Records covering seven years' work on legume and grass species in pure and mixed seedings for hay and pasture have been prepared for publication. A manuscript has also been prepared on certain factors influencing the success of plantings of the small-seeded legumes. Sweet clover species, varieties and strains are being compared; Iowa Late White, a strain especially desirable for pasture because of its long season of growth, has given promising results since its release in 1935. Results indicate that three cuttings of alfalfa per annum with the last cut taken about September 1 has resulted in a maximum yield of good quality hay and the maintenance of a good stand.

Data collected on a comparison of foreign, imported and American red clovers are being summarized for publication.

Ladak lucerne is more wilt resistant than any other variety commercially available, has a somewhat greater winter hardiness than Grimm or Cossack and has out-yielded all other varieties. Tests of Grimm alfalfa from ten different American States and two Canadian Provinces indicate that place of origin is not important. Studies with alfalfa strains on wilt-investigated soils were continued on the basis of first and second crop yields, severity of wilt infection and root studies; Ladak seems to be the outstanding variety. Definite conclusions cannot yet be drawn on the effect of growing grass-alfalfa mixtures for reducing wilt losses. Winter hardiness and proper spacing are being studied.

Reed canary grass (*Phalaris arundinacea*) has continued vigorous and productive, having maintained a pure stand for twelve years when planted on relatively low-lying soil abundantly supplied with moisture. On dry upland it has greatly out-yielded other grasses through a period of a few years, but has since become unproductive and is now replaced by Kentucky bluegrass. Replicated plantings have been made to compare different rates and methods of planting and to study the sod-bound condition observed on upland soils.

Definite conclusions cannot yet be made as to the best stage for cutting medium red, mammoth red and alsike clovers. American strains of medium red clover are to be compared. One of the primary objects of the study of the effect on alfalfa of spring burning of natural mulch material is to determine the effect of this practice on the prevalence of leaf diseases in the following season. No significant differences can be reported.

Permanent pasture has been improved by liming, reseeding and fertilization. The reseeding mixture consisted of 5 lb. biennial white sweet clover, 3 lb. medium red clover, and 2 lb. of alsike clover per acre, drilled into the grass sod at the end of March and the beginning of April. It is not known whether newly seeded clover may possibly survive relatively close grazing in the spring better than the relatively severe competition of a heavy grass growth. In order to obtain information on the effect of different harvest practices on the productivity of *Poa pratensis*, six harvest treatments, simulating as many different pasture management practices, have been carried on through four seasons, beginning in 1933; rotational grazing may be expected to give greater returns than continuous grazing (H. D. Hughes, Response of *Poa pratensis* L. to different harvest treatments, measured by weight and composition of forage and roots. *Rep. Fourth Int. Grassl. Congr. Gt. Brit.* 1937. pp. 447-52.)

Continual close harvesting either at 10-day or 40-day intervals resulted in a smaller, less adequate root system than when more growth was allowed to remain. The effect on the rhizomes was more striking than on roots and most striking in the unfertilized series. It may be expected that the 40-day harvest permits a more abundant transfer of material to the roots and the fact that this was not in evidence from the yield records may be because the sod was somewhat less dense when cut at less frequent intervals. Fertilization had a marked effect on root growth in the 0-4 in. horizon and comparatively little effect below the 4 in. level. Rhizome development was increased to a greater extent than the roots. The ash content of the

rhizomes was actually reduced, while that of the roots was somewhat increased as a result of fertilization. The nitrogen content of both the root and rhizome was increased.

Certain new forage crops show promise of adaptation to local conditions ; these include Mukden soybean, and Early Korean lespedeza.

The following may be mentioned among the projects of the Soils Sub-section : (1) effects of fertilizing materials and methods of grazing on soil conditions and plant growth on permanent pastures ; (2) relative value of red clover, alfalfa and sweet clover as soil-building crops ; (3) value of commercial cultures for the inoculation of legumes and non-legumes ; (4) effects on crop yields and soil conditions of small applications of fine limestone drilled in the row for starting new seedlings of legumes on acid soils (see A. A. Klingebiel and P. E. Brown, *J. Amer. Soc. Agron.* 29. 944-59 and 978-89. 1937, and 30. 1-9. 1938) ; (5) occurrence and activities of legume bacteria in acid soils as influenced by soil treatment ; (6) decomposition of leguminous green manures in acid and limed soils.

The Botany and Plant Pathology section is studying : (1) Germination of injured weed and crop seeds, and (2) impermeability and viability of seeds of native and introduced legumes (*Iowa State Coll. J. Sci.* 12. 5-24. 1937). Hulled weed seeds possess much less viability than do normal seeds ; allowance should be made in analyses reports. Some injured seeds of sweet clover, alfalfa, sorghum and flax, normally classed as inert, are able to produce normal seedlings. Mature seeds of *Amorpha fruticosa, Lespedeza capitata, Lespedeza virginica* and *Strophostyles helvola* (*Iowa State Coll. J. Sci.* 12. 25-35. 1937) possess a high degree of impermeability ranging from 65 to 89 per cent. Soybean seeds of two varieties, Wilson and Cayuga, contained 40 and 80 per cent hard seeds respectively. Shaking practically eliminates impermeability.

In a study of the relation of plant cover to erosion control, observations have been made on various woody plants, grasses and legumes. Oak-hickory woods and blue-grass pasture showed erosion to be reduced to insignificant amounts when areas are not over-grazed. An extremely dry or wet condition of the soil tends to increase the quantity of silt eroded. Interception of rainfall by the above ground parts of plants was as high as 60 per cent for complete woodland cover during light rains. For rains greater than an inch, interception was never more than 6 per cent. The most important factor limiting plant development in the open plot as compared with the wooded plot was probably surface soil temperature, which reached maxima of 150°F. several times during the summer.

Other studies by this section include : (1) influence of *Pythium* spp. and other fungi on seedling stands of legumes and other crops ; (2) sugar production and storage in the sugar beet ; development of strain suitable to Iowa conditions and methods of seed production ; (3) properties and herbicidal action of sodium chlorate mixtures ; (4) biology and control of nursery diseases of plants used in soil conservation ; (5) storage and translocation in dandelions (*J. agric. Res.* 56. 855-68, 1938). See also *Herb. Abstr.* 8. Abs. 1630. 1938.

Iowa Corn Research Institute

This Institute was organized as a part of the Iowa Agricultural Experiment Station and of Iowa State College at the beginning of the fiscal year 1935-36. The publication reviewed was the second annual report of the Institute.

The field of investigation covered is divided into eleven main sections and a number of sub-sections, as follows :

1. Soil and soil management as related to corn production.
   - A. Soil surveys.
   - B. Soil fertility and crop rotations as related to corn yields.
2. Cultural methods and equipment for corn production.
   - A. Methods and equipment for seedbed preparation, planting, cultivating and harvesting.
   - B. Methods, equipment and buildings for curing and storage of corn.
   - C. Corn production as related to weeds and their eradication.
   - D. Corn production as related to seed, time of planting and adaptation.
3. Corn breeding.
   - A. Collection and preservation of types and varieties of corn.
   - B. Development of pure inbred lines.
   - C. Development of hybrids and varieties commercially significant.
   - D. Corn genetics.
4. Botany of corn.
   - A. Physiology.
   - B. Ecology.
5. Pathology and mycology of corn (diseases of corn).
   - A. Fungi which attack corn.
   - B. Bacteria which attack corn.
   - C. Pathological anatomy of corn.
   - D. Methods of combating diseases of corn.
6. Insects of corn.
   - A. Life history studies.
   - B. Physiology and toxicology of corn insects.
   - C. Control measures.
7. Corn composition (chemistry and characteristics as a raw product).
   - A. Mechanical analysis and separation of corn.
   - B. Chemical composition of corn and of the corn plant.
   - C. Chemical analysis of corn derivatives.
8. Industrial utilization of corn.
9. Corn and corn products in human and animal nutrition.
10. Economic phases of corn production and utilization.
    - A. Supply and production of corn.
    - B. Corn marketing and transportation.
    - C. Public policy related to corn belt agriculture.
11. Corn history, literature and bibliography.

In the second section the projects include studies of accuracy of 4-row corn checkrowers, efficiency of corn pickers, seedbed preparation, production methods and equipment, and hill spacing of check-planted corn. Other projects in this group are studies of weed control and of the physiology of *Convolvulus arvensis* and other noxious weeds.

In the botanical studies on corn, attention is being devoted to the following problems: (1) physiological response of the growing plant and the pathogen to chemical treatment of seed corn; (2) effect of organic mercury dusts on seeds of corn, oats, barley and flax; (3) comparative study of the stem and root development of some varieties of field corn grown in Iowa, as regards the anatomical features manifested at successive stages of development; (4) translocation gradients and their relation to photosynthesis and yield; (5) measurement of the limiting environmental factors in the growth of the corn plant at different rates and spacings.

KENTUCKY

A special study was made of a sub-marginal area in western Kentucky. The farms averaged 63.5 acres; more than one-third of them had no well-situated land, and only about half had as much as five acres of such land. The number of persons per family averaged 5.5. The cash income averaged 68 dollars per family for the year. A few crops of corn exhaust the humus supply of freshly cleared hillside land, thus permitting erosion, which if not controlled, renders the land unfit for growing either corn or timber. The land area may be divided into three classes, (1) uninhabited (7 per cent), (2) largely in farms, but unsuitable for agriculture (76 per cent), and (3) fairly good agricultural land (17 per cent). The study warrants the following conclusions. Land in class 1 should be reserved for permanent forest. Almost all the land in class 2 should eventually be abandoned as farmland and reserved for forest use. The owners and operators of farms in class 3 should find means of making the maximum use of their land resources, that is, they should farm as intensively as is practical.

Certain legumes are grown in lysimeters alone, in association with bluegrass, or followed by a rye cover crop. There is considerable leaching of nitrogen in the field after legumes which die early in autumn, such as lespedezas and red clover in the second year, unless a grass is seeded with them, or a small grain crop is seeded in the early autumn after them.

Studies of the relation of soil productivity to red clover failure support earlier evidence that the environmental factor of low soil productivity in itself affects unadapted and adapted red clover similarly; adapted varieties appear to be no better suited to grow on poor soil than are the unadapted kinds.

In trials with continuous and alternate grazing on permanent pastures some measures of the productivity of pastures in the Central Bluegrass region and an idea of the possibility of their improvement through management practices have been obtained.

Research in developing new strains of red clover is proceeding; one such strain

was to be tested in field trials in 1938 to determine its value. A new and promising strain of orchard grass (*Dactylis glomerata*) is being tested. Strains of bluegrass (*Poa pratensis*) have been selected for drought resistance. They varied as much as 300 per cent in yield of dry matter during the year and were strikingly different in herbage production throughout the growing season. It appears that distinct varieties of Kentucky bluegrass have developed on all bluegrass fields. Korean lespedeza has a very beneficial effect upon the growth of bluegrass. Less care is required to maintain bluegrass-alfalfa mixtures than with many other legumes.

During 1937 all varieties of alfalfa were severely injured by leaf hopper (*Empoasca fabae*). The total yields for the season of some of the varieties were :

	Lb. per acre
Hardigan	7265
Kansas certified common	5500
Grimm	4845
Oklahoma " adapted "	4100
Arizona common	2415

Chemical analyses of Kentucky bluegrass, orchard grass, etc., have shown that crops grown on the highly phosphatic soils of the Bluegrass region contain two or more times as much phosphorus as crops from low phosphorus soil.

A simple method has been developed to give rapid determination of the carbon in carbohydrate and protein compounds in plant tissue in a large number of samples.

The function of boron in the metabolism of sweet potatoes was studied in purified sand cultures. Those given near-toxic quantities of boron and then deprived of boron developed characteristic symptoms. Excessive quantities of starch were stored in the leaf and stem cells of plants deficient in boron, and cracks and seams were often observed in the otherwise apparently normal plant tissues. Plants grown in a low-boron culture contained less boron in the growing point than in the older leaves. This condition indicates that the boron is not translocated from the older to the newly formed tissues, as is the case with some other elements essential in metabolism.

The resistance of clovers (Kentucky 101, Tennessee, Louisiana and North Carolina), to pea aphid infestation has been studied ; the Kentucky and Tennessee clovers showed very much greater resistance.

On the Western Kentucky Sub-station, lespedeza has given a large response to good soil treatment. Comparative yields are given of hay and of corn and wheat, which follow lespedeza in the rotation.

A comparison is also being made between treated and untreated pasture as expressed in live-weight gains per acre. It is noted that on the rock phosphate treated field there was a very heavy stand of excellent growth of hop clover (*Trifolium procumbens*) during the early summer.

MARYLAND

The report of this Station commences with a short introductory section dealing with the current research of the various departments in the Station. The great bulk

of the publication is taken up by Bulletins 397 to 409, which have been completed during the year.

AGRONOMY. Research in crop production has been chiefly concerned with methods, crop combination and rotation studies, the response of field crops to environment, and the adaptability of varieties and strains to Maryland conditions.

Among forage crops most attention has been given to legumes. Work on the adaptability of alfalfa to climatic conditions was started in 1890. Between 1907 and 1917 an intensive study of its adaptability to various soils was made. More recently, work has been done on the determination of the adaptability of alfalfa from seed of various sources and on the management of the crop; the latter especially when grown in combination with other forage plants, and also with reference to maturity at harvest time. Several hundred varieties of soybeans have been tested for hay and soil production since the first tests were made in 1888. The Virginia brown bean and the Wilson-Five, a black bean, proved best for hay purposes. Similar work is in progress with cowpeas.

Red, alsike, crimson and sweet clovers have been studied from the standpoint of hay, soil improvement and pastures. With red clover, source of seed and resistance to anthracnose are the chief problems. Alsike is interesting in its wide adaptation to soil conditions and its favourable combination with alfalfa. Sweet clover is important as a pasture plant and for soil improvement.

Work has recently been commenced on the relative importance of grasses for turf and pasture on various soil types. This has led to an attempt to extend the lush pasture period by the use of various species of grasses and also to a study of strains of pasture grasses. A State-wide survey of the permanent pastures of Maryland was made in 1935 (Bulletin 373).

PLANT PHYSIOLOGY. Much of the earlier work in this laboratory was concerned with mineral nutrition, many of the problems of which can be solved only by carefully controlled water and sand culture methods of the plant physiologist. The knowledge of the essential role of some of the rarer elements, particularly boron, has been extended. Symptoms resulting from a deficiency of each of the various essential mineral elements were studied and described. The physiology of cold and drought resistance has been investigated in foreign and domestic red clovers. The use of growth regulators or hormone-like substances has opened up a new field in research.

MASSACHUSETTS

An economic study has been made of pasture improvement and soil management practices in relation to dairy farm organization. The Department of Agronomy is conducting a number of projects including the following: In the study of the magnesium (Mg) requirements of plants, analyses of mangels, potatoes and rutabagas indicate that, where the magnesium is applied, the amount in the plants is increased. This is not so in all cases with calcium.

The problem of herbage production in Massachusetts, in the opinion of the writer, centres mainly around soil fertility. If other factors such as weather, physical soil conditions and management practices are reasonably favourable, not only the

maintenance of particular species in many cases, but also the herbage yields of all species are primarily functions of soil fertility. The struggle in Massachusetts is to provide a level of soil fertility which will maintain high yielding species, such as Ladino clover. Fertilizer topdressing alone will not accomplish this result. Tillage, fertilizers, organic matter and seed are all important factors in establishing and maintaining productive species in productive pastures. If pastures are cared for and treated as any other high-producing crop, they will yield in a comparable fashion.

Research with alfalfa includes effect of time of cutting on yields, and the use of potash in preventing winter killing ; the portion which received potash was more winter resistant and produced a better stand, while the non-potash plants were winter-killed. Hardigan and Ontario variegated varieties were outstanding in yield and winter hardiness.

Varieties of corn are being tested for grain and silage.

Studies are being made of the herbicidal properties of calcium cyanamide when used on soils previous to sowing seeds of turf grasses and of its effect on surface weed seeds on established lawns.

It is found that a peculiar disease of cattle diagnosed as " nutritional anaemia " is due to lack of available iron in the sandy soils of the affected region, which makes the iron content of the forage very low. The addition of an iron compound (iron ammonium citrate) to soils from farms where this disease has occurred resulted in a large increase in the percentage of iron in grasses on these soils.

The Department of Animal Husbandry is studying the chemistry of pasture grasses and is co-operating with the Chemistry Department in the study of the vitamin A content of pasture grasses. In 1936 the vitamin A content was determined in *Festuca ovina*, Rhode Island bent and red-top (*Agrostis* species), *Poa pratensis* and *Phleum pratense*. This work was continued in 1937 when *Dactylis glomerata* and *Anthoxanthum odoratum* were tested ; vitamin A content is higher from fertilized plots than from unfertilized ; the seasonal variation is not as great as that attributed to the application of commercial fertilizers.

A preliminary investigation is being made of the merits of molasses-grass silage for local conditions.

The Department of Botany is studying the following topics : soil temperature as an important ecological factor in green-houses ; the root system development of hardened plants ; damping-off and growth of seedlings and cuttings of woody plants as affected by soil treatment and modifications of environment.

MICHIGAN

Various problems of animal nutrition are mentioned in the report of the section on Dairy Husbandry. As much of the alfalfa hay in Michigan is low in phosphorus, the problem of the effect of supplementing a basic ration of low-phosphorus alfalfa with bone meal on the growth, production, and reproduction of dairy cattle is of great importance. Two articles and a technical bulletin have been published. In another study of the value of alfalfa hay in the ration of dairy cattle it has been

found that Michigan cereal grains, such as corn, oats and barley, give equally satisfactory results when fed with liberal amounts of alfalfa hay as the more complex and expensive grain mixtures. Feeding trials have also proved the complete practicability of alfalfa-molasses silage.

The Farm Crops Section reports on autumn management of alfalfa; the time when cutting is most injurious depends upon the occurrence of the first severe freezing weather. Heavy freezing in early October tends to make cutting in early September injurious, while later freezing delays the critical period for cutting until late September. Alfalfa was not injured by the removal of top growth after a killing frost, indicating that the autumn growth may be used for pasture or silage. By taking the first cutting of alfalfa in bud stage and the second in full bloom with late autumn growth used for pasture or silage, it seems probable that a system of management can be worked out whereby the quality of the first cutting can be materially improved without serious injury to the stand or reduction in yield.

Old alfalfa meadows, reduced in stand by winter injury and other causes, were made more productive by introduction of various grasses. Timothy, orchard grass, tall oat grass, and domestic ryegrass were most promising in 1935-36 trials, increasing yield by 500 to 700 lb. dry matter per acre.

Quack grass (*Agropyron repens*) when fertilized with nitrogen and cut early produces hay of high protein content and of good quality. The nitrogen fertilizer also increases yields. The nitrogen fertilization and early cutting appear to facilitate the control of quack grass by reducing food reserves in the underground portions of the plant.

Projects of the Soil Section include response of timothy meadows to fertilization (early spring top-dressing with 400 lb. 10-10-5 fertilizer), resistance of various *Agrostis* spp. to disease, effect of mineral and organic nitrogen on grass, increase of organic content of sandy soil with legumes, and nitrogen fixation.

MINNESOTA

The projects being studied are given in the order of their appearance in the report of the Agricultural Experiment Station.

Comparative studies of the biochemistry of normal and abnormal plants.

Subprojects: Acid preservation of green feeds. Cyanogenetic plants and factors in cyanogenesis: cyanide poisoning. Distribution of moisture and acid in silage. Sorghum × Sudan grass hybrids. Second year test of Sudan grass. Calibration of sodium picrate paper for HCN estimation. Tests for poisons in suspected plants and feed.

The chemical and physico-chemical properties of plant tissue fluids.

Protein investigations.

Subprojects: The acid amide nitrogen of proteins. (Dormant). The proteins of various tree seeds. Alkaline decomposition of cystine. Enzymatic determination of amide nitrogen. A study of homogeneity of zein. The denaturation of proteins. A method for the rapid determination of pepsin

in gastric juice. A study of the oat proteins. The action of the Grignard reagent on proteins. The enzymatic determination of papain. A protein "textbook-monograph."

The fundamental properties of colloid systems, with particular reference to biochemical problems.

Subprojects: The spreading and denaturation of proteins. The reaction between metaphosphoric acid and proteins. The colloidal properties of starches from the various species of *Triticum*. The electrokinetic behaviour of homologous series of the aliphatic alcohols, acids and esters on cellulose and Al_2O_3 interfaces. The electrokinetic behaviour of barium sulphate. Surface behaviour and oxidative behaviour of a series of vegetable oils and their chemical constituents. A colloid "textbook-monograph."

Soil erosion control by engineering methods and such in conjunction with field and cropping management.

The effect of deep tillage on the yield of root crops.

Varietal improvement of alfalfa and source-of-seed investigations.

Subprojects: Rod-row trials. Tests in replicated fortieth-acre plots of new strains and varieties for yield and quality of hay, and for cold resistance. Tests in replicated fortieth-acre plots of plantings from commercial lots of alfalfa seed.

Forage and pasture crop investigations.

Subprojects: Rod-row trials. Fortieth-acre plot trials.

Varietal improvement and studies on the fertilizing value of sweet clover.

Subprojects: Improvement phases. Variety tests. Methods of handling sweet clover in relation to the effect on the succeeding crop.

Physiological studies of crop plants.

Varietal improvement in field peas, soybeans and field beans.

Subprojects: Classification. Preliminary trials. Fortieth-acre plot trials.

Reed canary grass (*Phalaris arundinacea*) investigations.

Subprojects: Flowering and seeding habits. Improvement through isolation of superior strains. (Closed.)

The effect of self-fertilization in naturally cross-pollinated plants.

Subprojects: Red clover. (Closed.) Sunflowers. (Closed.)

Alsike clover seed production.

Subprojects: Rate of seeding and companion crop. Breeding.

Crop rotation investigations.

Co-operative seed production and distribution.

The development of disease-resistant varieties of farm crops.

Emergency fodder, hay and pasture crops.

The relation of insects to the spread, transmission and development of plant diseases.

Subprojects: The association of leaf hoppers with the alfalfa yellow top disease. Miscellaneous dipterous insects and bacterial soft rots. Insect transmission of various diseases of plants.

Pathological factors affecting the deterioration of stands of clover and other leguminous forage plants. (Closed.)

Effect of low temperature on plants.

Subprojects: Varietal differences in frost resistance of crop plants. Physiological factors concerned in frost injury. Desiccation in the frozen condition as a cause of injury.

Investigations on respiratory enzymes.

Subprojects: Oxido-reductase. State of oxidation in tissues.

Physiology of seed germination.

Subprojects: Physiology of dormancy in seeds, including a study of means to shorten or eliminate the rest period. Effects of seed treatment upon germination, subsequent growth, and yield.

Plant metabolism and growth.

Subprojects: Effect of length of illumination and light intensity upon growth and reproduction. Salt nutrition.

Seed studies.

Subprojects: Weed seed cases. Seed testing survey. Effect of chemical treatment on viability. Seed herbarium.

Weeds.

Subprojects: Chemical eradication. Weed identification and survey.

Growth habits and qualities of plants suitable for pasture.

Pasture management studies.

Subprojects: Renovating permanent bluegrass pastures. Comparison of delayed with continuous grazing of treated and untreated permanent pastures. (Dormant.) Comparison of the value of different mixtures of grasses and legumes. Comparison of sweet clover and Sudan grass as supplementary pasture crops. Comparison of methods of freeing permanent pastures from weeds and brush. (Dormant.)

Characteristics, growth habits, and control methods of weedy plants.

Subprojects: Cultural methods as a means of control, with special reference to field bindweed. The morphology and physiology of perennial weeds. Chemical eradicants in the control of weeds. The development of new chemicals for weed control. Weed dissemination.

MISSOURI

The Department of Animal Husbandry is studying comparative feeding value of legume hays for wintering native calves, molasses-alfalfa supplement to grain ration for calves, full feeding yearling steers on pasture and in dry lot, a comparison of systems of grazing *Poa pratensis* pastures, and forage crops for swine.

The Department of Dairy Husbandry is studying the comparative value of hays (Korean lespedeza, soybean and alfalfa) for milk production; lespedeza was least palatable, alfalfa most. Pasture investigations include fertilizer trials, tests with English pasture grasses, of which *Festuca pratensis*, *Dactylis glomerata* and

Phleum pratense (Scotch) are still producing high yields; *Lolium italicum* and *L. perenne* died in the first and second year respectively without producing seed.

The Field Crops Department is concerned with breeding barley as a fodder crop, rotation pastures and experiments on increasing the productivity of Missouri pastures by comparing three grazing systems (continuous, rotation and supplemented), in order to use *Poa pratensis* most efficiently and at the same time preserve the productivity of the sod; a combination of rotation and supplemented grazing satisfies all three of these requirements. The recent series of dry hot summers has emphasized the need for strains of *Poa pratensis* more resistant to drought and high temperatures, and also for more information regarding the temperature relations of the more important pasture grasses. A breeding programme is in progress to develop, through selection and hybridization, more resistant strains of *Poa pratensis*.

The Department of Horticulture reports on the research of A. E. Murneek and his associates on biochemical studies of photoperiodic effects in plants, the influence of length of day on the structural development of the soybean plant, variety Biloxi (see Missouri Agric. Expt. Sta. Res. Bull. 242, 1936, *Herb. Abstr.* 6. 317. 1936), and the separation of certain types of response of plants to photoperiods.

The Department of Soils gives a further report on the classic soil erosion investigations of M. F. Miller and his associates.

MONTANA

The Department of Agricultural Economics is studying farm and ranch management and organization in the dryland areas, a project which has been intensified because of the extreme drought and the low prices for agricultural crops. A ranch economic survey was made to determine the problems of range stockmen, who generally agreed that their range was not as good as when they first began their ranching operations; the principal cause of this was said to be drought. More conservative use of the range was considered desirable and it was thought that 75 per cent utilization of the normal grass crop would result in range improvement and help to stabilize ranch operations. Many doubted, however, whether they could carry out such a practice. Stock water development was apparently regarded as the most hopeful means for range improvement, but there appeared to be little definite knowledge about, or practice of, such proposals as deferred and rotation grazing, contour furrowing, etc. A good start has been made in Montana on working out the community range control problem and the number of State grazing districts has increased in number and in area.

The Department of Agronomy deals chiefly with crop adaptation and improvement, soil enrichment and weed control. In the crop adaptation work, projects involve varietal tests with cereals, alfalfa, grasses, etc. Soil fertility of irrigated land is increased by the use of three years of alfalfa and manure in the rotation. For weed control, three to five years of alfalfa, with grain and some cultivated crop in a rotation is generally efficient.

NEBRASKA

Field tests conducted in co-operation with the Division of Forage Crops and Diseases, U.S. Department of Agriculture, continue to show the superiority of the Hardistan variety where conditions are favourable for development of bacterial wilt, such as in the sub-irrigated valleys and under-surface irrigation. Under upland conditions, Grimm, Cossack, Ladak and Northern-grown Common are the most suitable varieties.

Selection and breeding for bacterial wilt resistance, seed productivity, and other desirable characters are being continued. Efforts are also being made to develop pasture-type alfalfas. Initial seed increase of desirable new types developed from selections and selfed lines has been made. A plan has been worked out by the Alfalfa Improvement Conference, composed of all interested alfalfa workers in the United States, whereby promising strains, including many from Nebraska, will be co-operatively tested throughout the country under a great variety of conditions.

Sweet clover experiments inaugurated in 1935, also in co-operation with the Division of Forage Crops and Diseases (see p. 12), include (1) improvement through selection and breeding, (2) determination of the best methods of planting small seed lots in limited field areas to secure accurate comparative data, (3) test of varieties for comparative hay, pasture and seed yields, (4) effects of cutting treatments in first and second years on hay, pasture and seed production, and (5) seed increase of promising varieties.

Selection and breeding work has been expanded and a nursery of several thousand spaced plants established ; emphasis is being placed on selection for inbreeding of individual plants, which by colorimetric determination appear to be low in coumarin. Genetical and cytological studies are being undertaken and artificial light is being used to break the biennial habit and cause early flowering.

Grass improvement work inaugurated in 1936 in co-operation with the Division of Forage Crops and Diseases is being conducted with sixteen cultivated and native forage grasses to determine the most feasible methods of establishing plants from seed and of producing seed in the greenhouse for hybridization work. Eleven cultivated and eight native forage species were seeded on an irrigated field for study under grazing conditions. Experiments on the eradication of the more serious and common perennial pasture weeds by mowing at proper times are being continued. Seeds of certain weeds germinate readily ; others only after exposure to low temperature.

Varietal trials are in progress with grain and forage sorghums. It is noted that soybeans leave the soil rather loose and bare and are often conducive to excessive erosion on rolling land. New interest in this crop has developed with the recent installation of two soybean processing plants in eastern Nebraska. This will doubtless lead to a material expansion in the acreage of soybeans in this State.

The bindweed research project, in co-operation with the Division of Cereal Crops and Diseases, has as its objectives the discovery of general principles from which control methods may be developed, and the comparison of promising practices. Clean tillage and the application of sodium chlorate are successful treatments.

In research on livestock feeding, the following aspects are being studied : corn

silage versus corn and wheat silage; grainless silage, cottonseed cake and a half-feed of corn for yearling and calf heifers; the seeding and carrying capacity of temporary pastures; full-feeding pigs on Sudan grass; corn and alfalfa hay rations for fattening lambs.

Work on determination of wilt and cold resistance of alfalfa selections ranging into the eighth selfed generation, together with a few varieties and strains, has been continued and some increase in seed of the more promising alfalfas has been obtained. The study has been continued on heaving of soil as it freezes; ice lenses of varying thickness have been produced and their influence on roots remains to be determined.

Vernalization is not a practical measure for Nebraska since yields from activated winter wheat seed have proved lower than those from autumn-sown wheat.

Much of the work at the North Platte Sub-station is in co-operation with the Division of Dry Land Agriculture, U.S. Department of Agriculture, and space has been provided for two grass nurseries for the Soil Conservation Service and for a study of native and cultivated grasses under irrigation. The other work at the Station includes experiments on feeding steers on native grass and alfalfa pasture, feeding on barley, the winter feeding of steer calves and the pasturing of a dairy herd on alfalfa.

NEVADA

The Department of Range Management is studying poisonous range plants which affect the local cattle and sheep industries. Species concerned include *Astragalus speirocarpus* and *Tetradymia glabrata*, which causes swell-head in sheep; studies are made on alkaloids in *Lupinus confertus* and *Corydalis caseana*, and on improved methods of testing soils for selenium. Other projects include feeding and finishing range ewes and lambs, economics of cattle and sheep production under Nevada ranch and range conditions, range conservation carrying capacity survey, and the economic study of range use and factors affecting ranch and range stability. A rotation paddock system of grazing by range flocks of sheep is also being developed on irrigated meadows. Observations are made of the seeding habits of brome grasses and competitive relationships between invading annual brome grasses and the native Nevada perennial grasses, to which problems the restoration of overgrazed sheep and cattle ranges in northern Nevada is closely related.

The Department of Farm Development has made a test of the economic efficiency of alfalfa hay as a sole ration for dairy cattle and its relation to sterility. The Department of Soil Fertility has studied various organic and inorganic phosphates with special reference to their ability to penetrate soils and to their positional and chemical availability to plants. When pots were divided by partitions and nutrient solutions varying in essential constituents were supplied to the roots in the various divisions, the growth of the plants indicated that nutrients must be supplied alike to all parts of the root system, in order to nourish the whole top of the plant, a conclusion of fundamental importance as regards the placement of phosphatic fertilizers in the soil. Definite local injuries and abnormalities in the plant were caused by an unequal distribution of nutrients which were fed in groups differentially. In 1936-37 analyses

were made which showed differences in the placement of nutrients in different parts of the top of a plant, or even in the two halves of the same leaf.

NEW JERSEY

The Department of Agricultural Biochemistry is studying the effect of processes on the nutritive value of field crops. These include investigations on grass silage preserved with molasses and corn silage preserved in the same way, determinations of the carotin content being made in each case ; the colorimetric carotin determination is a reliable index of vitamin A activity.

The Department of Agronomy is breeding new corn varieties resistant to lodging and suitable for ensilage. An important new development in grain production is the double cropping system, which makes use of winter barley and soybeans in one year with alternation of cultivated crops, such as potatoes, canning tomatoes, or vegetables. Tests with regional strains and varieties of *Trifolium pratense* have confirmed the inferiority of types from foreign countries which are unable to endure the summer weather. The most valuable strains are Kentucky Selection 101 and Tennessee disease resistant. Two new promising adapted strains of alfalfa are Norwis, and Kansas 308 which is resistant to wilt ; improved varieties are urgently required. In an attempt to improve the protein content of *Phleum pratense* hay, it now appears that soluble nitrogen fertilizers may be applied to timothy at time of heading or earlier, and that 30 to 70 per cent of the nitrogen so broadcast will be converted into plant protein in 10 to 20 days.

In a breeding programme to develop improved strains of alfalfa suitable for local conditions, the close correlation of strongly branched root systems with high-yielding ability and resistance to winter heaving is a significant development. In the breeding of *Trifolium repens*, preliminary observations indicate great variations in strains, not only in the rapidity with which they spread under pasture conditions and in the height of the plant, but also in seed setting ability. The adaptation of strains to various levels of soil fertility is now being studied.

Pasture studies have included a comparison of twenty-two seeds mixtures in conjunction with eight types of soil treatment, all plots being grazed periodically by the dairy herd. A comparison of the lime-minerals-clover system of pasture treatment with the lime-minerals-nitrogen system has shown that although nitrogen feeding is suitable for stimulation for very early spring growth, it is distinctly inferior to clover in the ability to produce feed from late June to early September. Experiments with lime-silicates have indicated great promise for this material as a means of stimulating clover. The addition of lime to pasture soils a year or more in advance of phosphate application has been an important factor in making phosphates more available. The supply of available soil phosphorus seems to be the most critical problem in the introduction of clover on pastures. The Department of Dairy Husbandry is also carrying out extensive pasture and grassland improvement work.

The investigations of the Department of Plant Physiology include : level of boron supply in relation to nitrogen metabolism in cotton, effect of aeration on the growth of oat plants in solution cultures, a biological test for the boron content of

seeds, manganese deficiency and toxicity studies in corn and cotton (range of concentrations for normal growth), boron deficiency and toxicity studies in corn and cotton (range of concentrations for normal growth), boron and manganese deficiency studies (comparison of monocotyledon with dicotyledon), iron, zinc and copper nutrition studies with corn, development and composition of plant tissues associated with the absorption and assimilation of nitrate as compared with ammonium nitrogen by plants grown with culture solutions of high and low salt concentration, growth of beet plants in sand culture with nutrient solutions varying in potassium concentration, but otherwise complete, effect of boron deficiency on the growth of tomatoes and on the rate of absorption of nitrogen from culture solution, growth of white clover in sand culture with solutions of low phosphorus concentrations.

NEW HAMPSHIRE

Soil fertility experiments include studies of hay on neglected hay lands, legumes (alfalfa) on neglected hay lands, the application of fertilizers to legumes in the Connecticut Valley and the top-dressing of old pastures. The difference in yield response in one of these old pastures is ascribed to the appearance of wild white clover in the plots when phosphorus and potash are applied and its non-appearance when none is used. In the other it has not been entirely possible to correlate this appearance with fertilizer treatment. The soil of the latter field is much lighter and may in itself limit clover growth due to holding insufficient moisture. The character of the vegetation produced with nitrogen alone is less satisfactory for pasture than where the other elements are used, or where complete fertilizers are applied. Nitrate of soda appears to be the best nitrogen carrier for the soils in one test, while sulphate of ammonia has ranked highest in another.

Bulletin 306, " Experiments with Grass Hay," summarizes tests with fertilizing and cutting grass hay at different dates.

Silage corn variety tests indicate that high yielding silage varieties not only give more succulence, but also return more dry matter per acre.

An experiment on pasture species is being conducted in order that it may be used as a trial ground for new species, either from local sources or from the Regional Laboratory at State College, Pennsylvania (see p. 16), and for the development of new species by breeding and selection. Plots with alfalfa proved to be the most palatable and produced the most forage, distinctly superior to plots with sweet clover, or with Dutch clover. This suggests that alfalfa should be included in pasture seedings on land adapted to the crop.

Plants of poison ivy (*Rhus toxicodendron*) sprayed early in the season with 20 and 40 per cent solutions of sodium thiocyanate showed no signs of recovery.

NEW MEXICO

Research on the value and productivity of sugar beet seed produced annually instead of biennially was begun in 1923, with the result that the sugar-beet seed industry is now well established in the south-west. Approximately two million

lb. of seed were produced in the Rio Grande Valley in 1936 and the industry has expanded into Arizona, south-western Utah, Nevada and California. It is expected that within a few years practically all the sugar-beet seed planted in the Western States will be of domestic production. The industry is at present largest in Arizona, where more than 4,000 acres were grown in 1937. Many new problems have arisen and it is especially noticeable that various strains and varieties may show wide variations in seed yield.

Variety tests of corn (maize) have shown that most of the Mexican June strains gave significantly higher yields ; in particular the Arizona strains, Arizona and Sacaton Mexican June, gave significantly higher grain yields than the New Mexico strains. On the other hand, the New Mexico strains were considerably taller than the Arizona strains, indicating a higher silage-yielding ability.

Three of the treatments used for the eradication of Johnson grass (*Andropogon sorghum* var. *halepense*), namely, periodic hoeings of one and three weeks and chlorate sprays, offer possibilities on permanent irrigation ditch banks.

An alfalfa variety test containing eight varieties in a 4 × 8 radomized block was started in the autumn of 1935. Hairy Peruvian and the Common strains produced higher yields than the more cold-resistant types, which in turn carried a slightly higher percentage of leaves.

The annual legume variety test of 1936 produced results very similar to those of previous years. The crops being tested include soybeans, cowpeas, mung beans, velvet beans, Tepary beans, etc.

A rate and method-of-planting test of *Sesbania* was repeated ; there was no significant difference in the green manure yield of 20, 30 and 40 lb. of seed to the acre, broadcast and harrowed in, and 30 lb. seeded with a grain drill in 7 in. drills. Yields were significantly lower with 15 lb. of seed to the acre in 14 in. drills. Weed competition was worse with both drill plantings. *Sesbania* is an excellent soil-improving crop, producing a heavy growth in a short time. An annual winter legume green manure test was conducted with Austrian winter peas, hairy vetch, sour clover (*Melilotus indica*), and biennial white sweet clover planted on a uniform seeding of barley.

In tests with forage crops, Honey and Gooseneck, two very late sweet sorghums, gave a much higher yield of silage than the standard Mexican June corn, but carried much less grain. All grain sorghums gave a lower yield of silage, but had more grain in the silage than Mexican June corn. Manko and Premo were the outstanding grain sorghums, but were considerably later than hegari.

Dry-farming investigations in north-eastern New Mexico were conducted with corn, grain and forage sorghums, millets and beans. The 1936 precipitation was only 60 per cent of normal and wind erosion was very serious.

A study of the composition of range grasses and browse gathered at varying stages of maturity was started in June and August of 1936, four grasses and *Atriplex canescens* being grown in one enclosed plot and sampled four times each year. The objects of this project are to determine, (1) the composition of important range pasture plants at different seasons, (2) the loss or variation of nutrients occurring

through wintering or leaching. The most important range grasses included are: *Bouteloua eriopoda, B. gracilis, Sporobolus cryptandrus, Hilaria mutica, Muhlenbergia porteri, B. curtipendula, Sporobolus airoides, Distichlis stricta,* and *Panicum obtusum.* Preliminary observations seem to suggest that :

(1) There is a positive correlation between available soil phosphorus and phosphorus content of the forage ; soil moisture seems to be another factor which affects the phosphorus content of the forage ;

(2) When two species of grass grow on the same type of soil and in close proximity, the deeper-rooted plant is usually the higher in phosphorus content ;

(3) Black grama (*Bouteloua eriopoda*), which generally remains green for about two-thirds the length of the stalk during the entire year, probably furnishes most, if not all, the vitamin A requirements of range cattle in this area.

Work has been done on the increase or decrease of pingue (*Actinea richardsoni*).

The results of a study of the calcium and phosphorus content of the important live-stock grazing forages, in different sections of New Mexico in which the areas deficient in these two elements were located, have been presented in Technical Bulletin 246.

Studies of the revegetation of south-western ranges by controlled grazing, utilization of run-off water, and reseeding are discussed under three separate heads, namely : natural revegetation, artificial revegetation, and the determination of the carrying capacity of the ranges.

NEW YORK

The following are some of the projects being studied at Cornell University.

Department of Agronomy

Nitrogen fertilization for timothy.

The protein content of timothy and of alfalfa cut at several progressive stages of growth.

A study of making legume inoculants.

Influence of legumes on the nitrogen content of non-legumes when plants are grown in association.

A field-crop survey of New York, and soil-and-field-crop studies.

The percentage of certain inorganic constituents of pasture herbage occurring at various places in New York.

A pasture survey of New York.

A test of grasses and grass associations for pasture purposes. (See D. B. Johnstone-Wallace—The influence of wild white clover on the seasonal production and chemical composition of pasture herbage, and upon soil temperature, soil moisture and erosion control. *Rep. Fourth Int. Grassl. Congr., Gt. Brit.* Section 2: 188-96, 1937. *Herb. Abstr.* 8. Abs. 353. 1938).

Department of Animal Husbandry

The carrying capacity of improved New York pastures as measured by live-weight gain on steers.

A comparison of various forage crops as temporary pastures for lambs.

A comparison of various rations as creep feeds for hothouse lambs.

The influence of quality of protein in the concentrate on the production of dairy cows fed mixed hay and corn silage as roughages.

A study of the use of molasses and phosphoric acid in making silage from legumes and grasses.

The nutritive value for farm animals of the proteins furnished by common protein-rich supplements and by typical legume and non-legume rations.

A study of different systems of pasture improvement, and the adaptation of each system to New York conditions.

A study of seed mixtures for permanent pastures in New York. (See R. B. Hinman—Live weight gains as a measure of pasture yields. *Proc. Amer. Soc. Anim. Prod.* 1937. pp. 83-4. *Herb. Abstr.* 8. Abs. 1093. 1938.)

Department of Botany

Taxonomic and habit studies of New York plants.

The morphological nature of floral organs.

The developmental morphology of the corn plant.

Determination of the viability of weed seeds under field conditions.

Studies on the identification of seeds.

Studies on the translocation of solutes in plants. Tissues concerned in translocation, and factors influencing the rate and direction of movement.

Studies on the effects of transpiration on plants.

The relation of manganese to plant growth.

A study of the relation of copper to the growth of plants.

Physiological studies on the influence of sugar on green plants.

An investigation on the direct absorption and utilization of amino acids by plants. (See E. M. Palmquist—The simultaneous movement of carbohydrates and fluorescein in opposite directions in the phloem. *Amer. J. Bot.* 25. 97-105. 1938. John Shafer, Jr.—Effect of light on CO_2 in leaves. *Plant Physiol.* 13. 141-56. 1938. *Herb. Abstr.* 8. Abs. 759. 1938.)

Department of Plant Breeding

Breeding silage corn for increased yield.

Breeding soybeans for grain and forage.

Breeding alfalfa for winter hardiness and yield for hay or pasture.

Breeding field and garden beans for disease resistance, yield, and quality.

NORTH CAROLINA

The application of fertilizer and/or lime to crops such as soybeans, corn, lespedeza, red clover, miscellaneous legumes and hay has been studied.

Legume and grass investigations include varietal trials of soybeans for hay, utilization of *Crotalaria* species, acid-tolerant legume and grass nursery, environmental factors affecting the establishment of permanent pastures, and a study of cowpeas resistant to wilt.

Dairy investigations include a study of the use for dairy cattle of the whole peanut plant after being ground and fed; the effect of fertilizers on dairy cattle pastures; kudzu (*Pueraria thunbergiana*) and *Lespedeza sericea* as supplementary pastures, feeding of roughage, utilization of the corn-cotton-legume rotation, feeding beet pulp, and digestion trials on *Lespedeza sericea*, peanut hay, whole peanut plant and on early- and late-cut medium hay consisting largely of timothy and clover.

Among the animal husbandry investigations is a study of pastures (Korean lespedeza sown with both rye and ryegrass) and their utilization by sheep, the value of, and comparative gains on, native reeds (*Arundinaria tecta*) for the summer grazing of beef cattle, vitamin A, B (B_1) and flavin components in soybeans and cowpeas.

NORTH DAKOTA

Continued dry seasons have hampered progress in breeding alfalfa. Varietal trials have been made for winter hardiness and forage yield in alfalfa and sweet clover.

The Department of Animal Husbandry is studying the influence of intensity and rotation of grazing on the character of the range and the quality and palatability of the beef produced. Sweet clover diseases of cattle have been studied; the chemical entity which develops in the sweet clover in the process of spoiling and which is responsible for the alterations in the animal is still unknown.

The Department of Botany and Plant Pathology is studying growth, reproduction and control of leafy spurge (*Euphorbia virgata*), management and improvement of range land in Western North Dakota (H. C. Hanson, *J. agric. Res.* 49. 815-42. 1934), relation of vegetation type to soil type in Western North Dakota, composition and value of slough hay, life-histories of annual weeds, and the eradication of barberry. Ergot and blight of grain crops developed in an epidemic form in the summer of 1933 and sclerotia *Claviceps purpurea* were observed on a number of grasses, including brome, western wheat and quack grass (*Agropyron* spp.).

OHIO

The Department of Agronomy is stressing the fact that the maintenance and improvement of soil productivity depend first of all upon the cropping system, a fact which is true whether exhaustion or erosion is the chief factor causing soil deterioration. A comparison has been made of the effects of 20 years' cropping under different rotations in which corn as the chief crop is combined with wheat or oats and clover or alfalfa. The value of soybeans as compared with oats was also studied. Since the legume crops are the restorative crops of the rotation a failure of seedings must be avoided ; as a result the improvement of seeding methods has been a major project in recent years. An important feature of the results was the excellent stand, especially of red clover and timothy, obtained after mulching with a light coat of manure or a ton of straw, both carefully spread with a manure spreader immediately after sowing the forages. Despite the fact that the season was very favourable for summer seedings, the method of seeding in cultipacker furrows gave nearly twice as many alfalfa plants as any method using the drill. As it had been observed that *Poa pratensis* pastures on similar soils and with similar fertilizations differ widely in yield, stand and weed content, a study was made of the effect of closeness of grazing on the yield and stand of these pastures. Results indicate that permanent *Poa pratensis-Trifolium repens* pastures should be maintained at a height ranging from 1.5 to 5 inches. Special attention has been devoted to hybrid corn. Other studies include the value of the new, late-flowering variety of sweet clover (Evergreen) bred and produced by the Station ; compared with ordinary biennial white sweet clover, Evergreen is taller, starts flowering later, has a longer flowering period and remains green one to three weeks later in the autumn of the second year. These habits make it especially useful for second year pasture. It does not, however, set seed as abundantly as earlier varieties.

The Dairy Industry section is studying the use of mineral acids in the preservation of legume silage, the provision of pasture supplements of legume, Sudan grass or alfalfa pasture.

OKLAHOMA

Dairy investigations include a comparison of good quality prairie with alfalfa and the use of mungbean silage (*Phaseolus Mungo* L.) for milk cows. Soil and crop investigations include legume crop failures, cultivation of sweet clover in rows and the application of phosphates to winter legumes and of fertilizers to alfalfa. Winter cover crops (vetch, Austrian winter peas) and pastures are important for erosion control. Korean lespedeza is becoming increasingly popular in Western and Southern Oklahoma as a summer pasture legume. Arizona tepary beans (*Phaseolus acutifolius* A. Gray, var. *latifolius* Freeman), mungbeans from various sources and numerous native legumes are also being tested. Soybeans are studied as a substitute for cottonseed oil and meal. Cowpeas are adapted to a wider range of soil and climate and are used extensively. More hardy strains of alfalfa are desirable. Native grasses being tested for re-introduction into farming practice include grama

(*Bouteloua*), big and little bluestems (*Andropogon furcatus, Andropogon scoparius*), Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*) and buffalo grass (*Buchloë dactyloides*). A valuable strain of buffalo grass which is making very satisfactory yields of hay is being increased. Research is in progress on drought resistance in sorghums and Sudan grass. Oklahoma or Kansas-grown seed of alfalfa will produce stands that will survive longer than those from the more expensive seed sources, although they may not necessarily provide more hay.

The Animal Husbandry Department is comparing alfalfa prairie hay and wheat pasture for fattening lambs. The management of native pastures constitutes a major problem for range men in Oklahoma. The aim of research has been to determine: (1) the amount of beef that can be produced with a combined system of deferred and rotation grazing compared with a system of continuous grazing, (2) the effect of a combined system of deferred and rotation grazing on increasing the desirable forage and decreasing the amount of weeds produced, (3) a practical system of grazing based on the physiological requirements of the native grasses.

OREGON

Under the heading "Research discoveries" it is noted that a substantial seed industry has been established by the introduction and development of such seed crops as Austrian winter field peas, Hungarian hairy and purple vetches, Ladino and crimson clover, bent grass, etc. This has been made possible largely through the co-operation of the Bureau of Plant Industry, U.S. Department of Agriculture.

The Department of Agricultural Economics is studying the costs and carrying capacities of farm pastures. Records for 1934 have been published in Circular of Information, 129.

The Division of Animal Industries is concerned with lamb fattening trials on alfalfa-hay fed with barley, as compared with vetch-oat hay; irrigated pastures provide the best source of succulent fodder during the summer months, but their drawback is a tendency for the spread of internal parasites. Under the Dairy Husbandry section the feeding value of apples for dairy cows, ensilage made with molasses, and alfalfa-hay are being studied (Bulletin 328, 1934). Irrigated pastures provide succulent fodder; supplementary grasses with Ladino clover (*Trifolium repens* var. *latum*), although providing less carrying capacity, help to off-set the bloat problem (results to be published).

The Division of Plant Industries studies forage crops in co-operation with the Bureau of Plant Industry, U.S.D.A. The higher production and longer life of variegated and hardy northern alfalfa have been proved. The Willamette sweet clover is highly resistant to stem rot. Superior reed canary grass (*Phalaris arundinacea*) shows uniformity in production, which will facilitate mechanical seed harvest and cheaper seed production. The Station's strain of smooth crimson clover (*Trifolium incarnatum*) is resistant to stem rot, losses having been reduced by 50 per cent. Tests with *Lolium perenne, Alopecurus pratensis* and *Festuca rubra* var. *commutata* Gaud. [*F. fallax Thuill.*] (Chewings) have stimulated commercial pro-

duction. An attempt is being made to find a substitute for the tillage of alfalfa as it is believed that the planting of grasses and the absence of cultivation will give a higher yield of hay and longer life to the alfalfa plants, with less mechanical injury and less spread of disease.

In the Agricultural Chemistry Department projects include: nutritional problems associated with rations consisting principally or solely of alfalfa; biochemical factors influencing the feeding value of forage crops and the relation of forage crop quality to regional livestock disorders. Work is also in progress on sprays and spray residues.

PENNSYLVANIA

The Report for 1937 reviews the past 50 years' research at the Station, and includes the dedication of the U.S. Regional Pasture Research Laboratory (see p. 16 and *Herb. Rev.* 6. 146-50. 1938). This section is followed by progress reports of the various departments and by abstracts of Bulletins published between July 1, 1936 and June 30, 1937.

The list of current projects includes the following:

Farm Crops

- The effect of different fertilizers, lime and plaster and different amounts and sources on the production of corn, oats, mixed clover and timothy in rotation
- Varieties of soybeans
- Species, varieties and strains of alfalfa
- Pasture fertilization
- Testing and breeding grasses for pasture and other uses
- Growth and maintenance of fine turf grasses as influenced by various soil fertility factors
- The effect of different systems of grazing, cutting and fertilizing on white clover in permanent pastures
- The soil acidity tolerance of red clover strains and the nodule-forming organism associated with them

Plant Breeding

- Inheritance and breeding of red clover

RHODE ISLAND

The field crop research of the Department of Agronomy and Horticulture includes a study of legumes in seeds mixtures, of which only red clover succeeded in 1937; seed sources and varieties of soybeans for seed and forage, alfalfa-timothy mixture, Austrian field peas. Breeding of alfalfa has been continued and another generation of inbred lines obtained. A genetical analysis is being made of the inheritance of flower colour, type of growth, and resistance to leaf spot. The report of the Experiment Station also refers to grass and turf experiments on lawns and lawn grasses,

fine turf and turf grasses (*Agrostis* sp.), and the production of seed of *Agrostis*.

The Department of Chemistry, Plant Physiology and Pathology is studying the response of pasture grasses to varying amounts of moisture; the grasses include velvet bent (*Agrostis* sp.), *Lolium perenne, Agropyron cristatum, Dactylis glomerata* and *Poa pratensis*. Also the treating of compost with chloropicrin for weed seed control and the application of the same chemical to turf for the control of brown-patch and dollarspot (failure) are among experiments made.

SOUTH DAKOTA

As sorghums are becoming increasingly important as forage crops in South Dakota and the northern Great Plains, the question of forage poisoning of livestock, especially cattle, is being studied by the Departments of Agronomy, Animal Health and Animal Husbandry. A strain of Dakota Amber number 39-30-S with a low content of HCN has been selected (results being published.) Projects relating closely to field practices are conducted on the Agronomy Farm at Brookings; these include the following: (a) corn breeding for high and low protein, (b) trials with special crops, including canary grass (*Phalaris arundinacea*), tepary beans (*Phaseolus acutifolius* var. *latifolius*), and co-operative grass nurseries, and (c) perennial weed control (see Bulletin 305, "Field bindweed"). Soybeans may be grown as an annual legume in South Dakota. Comparison of seeding land to grass either in the autumn or in the spring is in progress; species are western wheat grass (*Agropyron smithii*), crested wheat grass (*Agropyron cristatum*), brome grass (*Bromus inermis*) and alfalfa.

The Animal Husbandry Department is studying various feeding problems including (1) feeding protein supplements with corn and alfalfa hay for the production of baby beef, (2) the fattening of range lambs, (3) fattening summer pigs on South Dakota grains, and (4) effects of pasture crop utilization by swine on the quality and palatability of pork.

The Department of Chemistry is studying "alkali disease" (selenium poisoning) including identification and isolation of the toxic constituents of grains, distribution of selenium in the bodies of animals fed with inorganic selenium and selenium occurring naturally in grains, geological distribution of selenium in South Dakota, its form in the soil, failure of sulphur to inhibit the absorption of selenium by plants, and analyses for selenium in grain, hay, straw and other plant materials, such as native range vegetation, and soils.

The Department of Dairy Husbandry is comparing sweet clover, alfalfa and Sudan grass pasture, the value of permanent grassland mixtures and the influence of roughage (alfalfa hay, prairie hay, beet pulp) on the vitamin D potency of milk.

The Department of Entomology has completed a study of the pollinating agents of sweet clover, with special emphasis upon seed production as influenced by the honey bee (results to be published).

TENNESSEE

The Department of Agronomy reports an extension of the project dealing with the improvement of red clover by the production of disease-resistant strains. It would appear possible to obtain strains completely immune to the most serious troubles, but difficulty has been encountered in keeping the strains up to a high standard and especially in obtaining seed for general use. Seed has now been grown in Oregon and other Western States, where it has proved superior to the kinds commonly grown there. A continued trial of Oregon-grown seed at the Knoxville Station proved, however, that the disease resistance was not maintained. It is, therefore, recommended that Tennessee farmers should include clover seed production among their activities, particularly as resistant varieties have always brought a premium price.

Crop improvement is also proceeding with winter peas, soybeans, corn and lespedeza. Other studies include the value of legumes in soil improvement and erosion control, and crop rotations.

The Chemistry Department is studying the production and value of new phosphates; chemical composition of annual and perennial lespedezas; and tannin content of plants.

The Plant Pathology Department reports progress in its studies of anthracnose-resistant red clover (see above.)

TEXAS

Studies have been made by the Division of Veterinary Science on loco weed (*Astragalus earlei*) poisoning, *Sartwellia flaveria* as a probable cause of hepatic cirrhosis in goats, *Gutierrezia microcephala* as the cause of abortion in cattle, and *Croton corymbulosis* as the cause of sudden and serious losses of cattle.

The Division of Chemistry is studying the relation of soil composition to plant and animal deficiencies, isolation of the toxic principle of the loco weed (locoine), variation in vitamin content of feeds, and quantitative occurrence of vitamin A in animal feeds.

The Division of Range Animal Husbandry is investigating the mineral requirements of cattle, mineral and protein deficiencies, and native and improved pastures in the Gulf Coast prairie of Texas.

The Division of Agronomy is investigating green manures for soil improvement, inheritance and improvement in corn, sorghums, and small grains, pasture improvement for East Texas, the genetic and cytological relationship between *Zea*, *Tripsacum*, and *Euchlaena*, varietal trials of winter and summer legumes, germination and longevity of bitterweed seed (*Actinea odorata*), effect of fertilizers on yield, chemical composition and botanical composition of pasture herbage, improvement of range and pasture plants by selection and breeding, and factors limiting pasture production, including effect of burning, and rational management of grazing lands.

The Division of Botany is concerned with the identity and distribution of native vegetation. The presence of vegetation as feed for livestock or as plants harmful to

livestock, or for their value as honey producers, as well as the presence of plants which act as carriers of plant diseases are important.

The Division of Swine Husbandry is studying the value of Sudan grass and oats pasture for fattening hogs, while the Dairy Husbandry Division is concerned with various pasture and nutritional (vitamin A) problems.

UTAH

The Agronomy and Soils Department is attempting to discover a variety of alfalfa resistant to weevil, nematode, and bacterial wilt. Alfalfa is the State's most important crop and at present yields are being materially reduced by insect pests and disease. A Turkestan variety has been found that is highly resistant to wilt, but has a low forage yield. Efforts are now being made to secure a cross which will give high forage yields as well as wilt resistance.

Strawberry clover (*Trifolium fragiferum*), a new legume introduced from Australia, promises to be well adapted to the low-lying wet alkali soils of Utah.

In order to assist in the improvement of the range land in Utah from which the vegetation has been depleted by drought, erosion and over-grazing, a project is under way with the objective of grass improvement. Grasses found suitable for dry farms and ranges are : crested wheatgrass (*Agropyron cristatum*), slender wheatgrass (*Agropyron pauciflorum*), western wheatgrass (*Agropyron smithii*), smooth brome grass (*Bromus inermis*), tall meadow oat grass (*Arrhenatherum elatius*), bluebunch wheatgrass (*Agropyron spicatum*), mountain brome grass (*Bromus carinatus*).

Hybrid corn for silage production has been tested and found to give superior yields to the varieties that have been commonly grown.

Experimental work on weed eradication over a period of years has produced the following results : (1) Tillage followed by alternate weekly cultivations over a period of two years was effective in the control of such weeds as white top (*Lepidium draba*), Russian knapweed (*Centaurea picris*), morning glory (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*). (2) Alternate weekly cultivation is much cheaper than weekly cultivation and just as effective. (3) Of the chemicals tested, sodium and calcium chlorates appear to be most effective. (4) Chemicals generally were not as effective in control as tillage. (5) However, in a weed eradication programme both chemicals and cultivation should be used, cultivation on the larger areas, with chemicals applied on places where tillage is difficult or impossible.

During the 35-year period of dry-farming experiments, the following contributions have been important : (1) No measurable difference has been found between autumn and spring ploughing. (2) A rough fallow saves water as well as soil during periods of torrential showers. (3) Application of manure has increased yields and quality of wheat. (4) Alternate cropping has produced a greater total amount of wheat than continuous cropping and at much less cost. (5) For each inch of rainfall, 0.93 bushel of wheat was produced.

In 1925 approximately 22 million pounds of alfalfa seed were produced in Utah, but by 1929 only 3 million pounds were grown with no appreciable recovery up to

and including 1937. Detailed studies inaugurated in 1925 have led to the following conclusions: Soils of medium texture and thin stands of alfalfa are best for seed production. Seed-crop failures have been characterized by occurrence of bud damage and excessive stripping of flowers which is partly attributable to insects, especially *Lygus* spp. Seed growers of an entire district should adopt a uniform practice with respect to selecting either all first- or all second-growth alfalfa for the production of the seed crop. Simultaneous occurrence of both first- and second-crop alfalfa provides *Lygus* bugs with most favourable conditions for multiplication.

Application of treble superphosphate to irrigated pastures not only increased the amount of forage produced, but chemical analysis showed a significantly higher percentage of phosphorus in the forage.

The Department of Animal Husbandry found in lamb-feeding experiments that barley and alfalfa constitute an excellent basal ration for fattening lambs, but that feeds such as sugar beet by-products or cottonseed meal increased gains and reduced costs.

Studies of sheep feeding on Utah desert ranges showed that sheep receiving adequate range forage do not require supplementary feeding. Analysis of sixteen dominant range plants in the region showed a fairly satisfactory nutritive ratio with a tendency towards an unbalanced mineral content due to low phosphorus.

A study of alfalfa by the Chemistry and Bacteriology Department showed that although leaves make up only one-fourth of the dry matter of the alfalfa plant, they contain three times as much protein as the stems. The protein content of the plant increases up to the first week of full bloom, then decreases. Digestibility of the crop decreases as plants pass the bloom stage and become more mature.

In studies of forage crop insects, the Entomology Department found the alfalfa weevil to be one of the most destructive insect pests of forage crops in the State. However, methods for its practical control have been established. The seed chalcid fly can be controlled by the alfalfa-seed growers if all growers within a district follow a uniform practice with respect to the selection of the crop that is to be left for seed production. This practice also helps in the control of the *Lygus* bug.

Grasshoppers and crickets have been especially destructive to range forage in late years. The Federal Government is now conducting a control campaign in co-operation with infested States.

Among the studies conducted by the Range Management Department is a survey designed to obtain information on range resources of the State (forage classes and types, their extent, location, proper seasonal use, and adaptation to different stock classes). Proper management practices, carrying capacity, reseeding methods and species of plants which might increase the production of overgrazed range lands were studied.

WASHINGTON

Co-operative investigations on the control of weeds are being conducted by the Bureau of Plant Industry, U.S. Department of Agriculture with the co-operation

of the Idaho and Washington Agricultural Experiment Stations; this Weed Control Experiment Station was organized in 1936.

The Department of Agronomy is studying the adaptability, cultivation and improvement of forage grasses. *Agropyron cristatum* is the highest-yielding hay species under Palouse conditions. Other superior grasses are smooth brome (*Bromus inermis*), mountain brome (*B. marginatus*) and slender wheatgrass (*Agropyron pauciflorum*). Three feet double-row plantings of crested wheatgrass yield considerably more seed than solid stands; seed yield is increased by applications of nitrogen. Thirty-five selections of crested wheatgrass and twenty-five of slender wheatgrass have been studied for comparative forage yields. Selections have been made from field plantings of slender wheatgrass, crested wheatgrass, mountain brome, orchard grass (*Dactylis glomerata*), tall meadow oat (*Arrhenatherum elatius*), on the basis of disease resistance, aftermath, leafiness of first growth, drought tolerance and seed qualities.

Alaska field pea sown at half rate is the most desirable nurse crop for use while establishing stands of alfalfa and sweet clover. Spring wheat may also be used, but often reduces the second year yield of the forage crops.

Ladak is the highest-yielding variety of alfalfa under Palouse conditions; other aspects studied are row versus solid plantings, hill versus row plantings, seeding rates, and effect of shading on the seed production of Idaho Grimm alfalfa.

The Madrids continued to be the highest-yielding sweet clover varieties. Inbred seed of sweet clover has been obtained for use in future breeding work; all varieties are open pollinated and most have displayed a high degree of self-sterility (see Bull. 365. *Herb. Abstr.* 9. Abs. 588. 1939).

Co-operative work on grass breeding and improvement has continued. Many selected plants were propagated in nursery rows and numerous additional selections made from native and introduced grass species. Data have been obtained on seasonal development, nature of stems and foliage, growth habit, maturity, drought resistance, seed production, probable forage value and minor characteristics. Controlled pollination work is in progress and an attempt has been made to hybridize the more promising grass species with the cereals. Cytological studies are also in progress.

The Division of Animal Husbandry is studying the nutritive value of important pasture grasses and of first and second year sweet clover hay; the Division of Dairy Husbandry the nutritive value of homegrown hay and silage rations for dairy cattle, utilization of cull apples as feed for dairy cows, and the nutritive value of pea cannery refuse.

The Department of Entomology is studying the influence of plantings of alfalfa on the abundance of the pea aphis in Western Washington. The Division of Plant Pathology is co-operating with the Division of Forage Crops and Diseases, Bureau of Plant Industry and the Soil Conservation Service on smut diseases of forage grasses (species of *Agropyron, Hordeum* and *Bromus*) in the Pacific Northwest. A survey has been made for mosaic as the cause of failure in alfalfa plantings.

Research at the Soil and Water Conservation Experiment Station includes studies of effect of plant cover on run-off and erosion, movement and balance of soil

moisture, tillage and cultivation practices for erosion control, cropping practices in relation to erosion control, terracing studies and tree planting ; a Soil Conservation Nursery was established at the Station for the purpose of observation, seed increase, production of tree stock, seed and plant collection and seed testing.

WEST VIRGINIA

The Department of Field Crops is concerned with acid tolerance and coumarin in sweet clover ; selection of strains with these characteristics is in progress ; also the value of winter cover crops (rye and vetch, crimson clover, and sweet clover in a corn-soybean rotation) in reducing erosion.

Pasture land is of great importance in West Virginia, nearly five million acres of land being devoted to this use. As a rule they have received little attention in the past and generally show evidence of marked deterioration in recent years. A comprehensive field study was made in 1935 with the help of the Soil Conservation Service, when 775 pastures in nine important pasture areas were examined as regards the amount and kind of vegetation present, soil type, depth of surface soil, amount of erosion, degree of slope, carrying capacity, grazing practices, available phosphorus and soil acidity. In the poorest of the nine areas an average of 5.3 acres was required per animal unit, while in the best areas the figure was 2.5 acres ; 10.6 per cent of the pasture sod in the poorest area was composed of desirable grasses and legumes, while in the best area this value was 46.9 per cent. Differences in soil type, degree of slope and amount of erosion partly accounted for the differences in type of vegetation. Over 85 per cent of the pastures was too low in available phosphorus and too high in acidity for good pasture growth.

Local experiments on application of lime, phosphorus, potash and nitrogen are providing guidance for the rebuilding of the pasture lands; marked improvement in stand and composition of pasture grasses has followed the liming and fertilizer applications and these effects have been maintained over a period of three years without additional treatment (results published). There is a close relationship between the stand of *Poa pratensis* and *Trifolium repens* and available phosphorus and percentage base saturation of the soil (results published). See also *Herb. Abstr.* 8. Abs. 491. 1938.

WISCONSIN

The Departments of Animal Husbandry, Biochemistry and Agricultural Engineering are co-operating in a study of the effects of alfalfa silage on dairy cows and their milk production.

The Department of Horticulture reports that a double application of nitrogen fertilizer to *Poa pratensis* sod around cherry trees produced a heavy mat of grass which conserved enough soil moisture to enable such trees to compare favourably with cultivated ones in growth and fruiting.

Work on field crops includes a study of Sudan grass to determine whether it is

safe to pasture; only short dark green Sudan grass contains dangerous amounts of poison. This type of herbage is most frequent on soils high in available nitrogen, but low in available phosphorus. Drought is only an indirect factor in causing development of the poison, in that it may cause small plants to remain small for a longer time. It will not make the crop dangerous if the plants are already of a good size. Frozen grass is not materially higher in cyanide content than unfrozen grass, but if favourable conditions follow a killing frost the Sudan grass will send forth new shoots which are apt to be very high in poison. The making of stunted poisonous grass into hay or silage does not change the cyanide content enough to make the crops safe for feeding. A pasture plan is given to assist in avoiding danger and the Wisconsin test for cyanide in Sudan grass is described. An attempt is being made to develop improved strains of this grass.

A comprehensive pasture investigation has been started in which the yields of forage are measured by recording the amount of milk produced and the gains or losses of weight by dairy cows grazing fields under different management. This method shows the actual effects of a pasture on animals as well as the effects of animals on the pasture. Some attention is being paid to quack grass (*Agropyron repens*) as pasture. The proper management of *Poa pratensis* does not avoid the need for supplementary pastures, such as Sudan grass.

Under Wisconsin conditions alfalfa yields best when cut twice a year; it is seldom necessary to use more than 10 lb. of seed per acre. Varieties of alfalfa differ considerably in their ability to flower, in spite of *Lygus* bug injury, with certain strains of Grimm showing the most resistance. Alfalfa strains also differ in their ability to survive under ice sheets, the percentage mortality ranging from 11 to 96 per cent. With Grimm, the most popular alfalfa of the State, the loss was 42 per cent. Unfortunately, none of the six relatively ice-resistant alfalfas is also resistant to wilt disease.

There are good prospects of eventually developing a much improved sweet clover; the following findings are noted: (1) coumarin and related compounds are responsible for its bitter taste and for the tendency of the spoiled hay to become poisonous; (2) the content of coumarin can be rapidly and accurately measured; (3) a species of sweet clover imported from Asia and Europe contains only a trace of coumarin.

As American-grown red clover seed was scarce in the spring of 1937, large quantities of foreign seed were imported. Foreign red clover seed, with the exception of Canadian, cannot withstand the Wisconsin summers.

Wisconsin hybrid corn has been proved drought resistant.

WYOMING

Many new varieties of grains and grasses are being tested in the nursery of the Agronomy Department in co-operation with the Bureau of Plant Industry. Canada thistles can be kept in check by a good stand of alfalfa in short rotation, because a thick stand cut twice a year retards vegetative growth and lessens the increase of the thistles.

The change which occurs in the range vegetation under various types of management and use is being studied.

The Chemistry Department has collected further information on selenium in the soil and its effects on plants and animals. Other types of plant poisoning include that caused by the ground lichen (*Parmelia mollioscula*) and the cyanide poisoning caused by arrow grass (*Triglochin maritima*). Analyses of native and cultivated forage plants for calcium and phosphorus have been continued; nearly all the types have sufficient phosphorus and a fairly good calcium-phosphorus ratio.

Selenium indicator plants are useful in locating the principal seleniferous soil areas in the western United States.

ADDITIONAL REPORTS PREPARED TOO LATE FOR INCLUSION IN PROPER ORDER

COLORADO

Agronomy Section. In a study of the factors responsible for HCN content in Sudan grass, old self-fertilized lines are being used, while new lines are being self-fertilized and introduced into the tests. There are indications that the ability to produce HCN is inherited and also that environment influences HCN content.

An attempt is being made to obtain new lines of alfalfa, resistant to bacterial wilt and winterhardy, and arrangements have been made with the Federal Government and associated States of the Mid-west for exchange of prospective breeding material.

Small grains, peas, high-altitude dryland and irrigated grasses, and alfalfa, with a minor list of forage crops are being investigated for high altitude purposes.

Botany Section. Reserves in bindweed and white-weed are studied in connexion with the control of these plants. Field tests are in progress to observe the effect of cultivation and length of interval between cultivations. Sprays are also being used.

Chemistry Section. The composition of alfalfa as affected by crop rotation and the character of the soil solution. Seasonal changes in nutritive value of native range plants.

Pathology and Bacteriology Section. Oat-hay poisoning and studies on *Suckleya, Suckleyana, Sophora* and onion.

Range and Pasture Management Section. Studies are reported on improvement of native range, artificial revegetation, native hay meadows and sagebush lands, and range research surveys.

Rural Economics and Sociology Section. An economic study of the range livestock industry.

KANSAS

Soil conservation. Soil fertility experiments. Influence of legumes and nitrogen-fixing organisms on the growth of plants and on the nitrogen balance. Soil and crop experiment fields.

Plant industries. Temperature relations of crop plants; (1) the rate of loss in cold resistance of varieties of wheat after the start of spring growth, and (2) the relation of nutrient level to cold resistance of winter wheat. Small grain and sorghum improvement, including breeding of forage sorghums. Varietal and cultural tests of soybeans and cowpeas. Miscellaneous legumes for forage. Corn production and improvement.

Alfalfa investigations in relation to winter hardiness and bacterial wilt. Particular attention has been given to the study of five phases of the problem of cold resistance and bacterial wilt in alfalfa.

(1) Correlation of storage of organic food reserves in alfalfa roots with other physiological processes affecting cold resistance.
(2) Methods of promoting the production and viability of alfalfa seed.
(3) Alfalfa breeding and improvement
(4) Adaptation of domestic and foreign species and strains of alfalfa to different environments
(5) Selection and hybridization for improvement of alfalfa

Pasture improvement investigations. Investigations have been conducted on eight phases of this project, as follows:—

(1) The management of livestock on bluestem (*Andropogon* spp.) pastures
(2) Effect of burning on bluestem pastures
(3) Eradication of undesirable plants from pastures
(4) Effect of frequency, height and time of harvesting on yield and succession of pasture vegetation
(5) Effect of fertilizers on yield and succession of pasture vegetation
(6) Grass and forage-crop nursery
(7) Grass-breeding nursery
(8) Co-operative pasture experiments

Physiological study of bindweed in relation to its control. The work of this project has consisted of studies of (1) the general nature and growth of the bindweed plant; (2) the effect of ploughing on this plant; (3) the seasonal variation in the place and extent of reserve storage in older plants undisturbed by cultivation, older plants in cultivated land, and year-old undisturbed plants; and (4) of seed viability and the effect of depth of planting on the rate of germination of seed.

Weed eradication. The work on this project has been concerned with the use of chemicals for field bindweed control.

Other studies in plant industries include the influence of the method of harvesting and storing alfalfa-hay upon its quality; a physiological study of the hard winter wheat plant (the physiology of the awns).

Animal industries. The use of silage for fattening beef cattle. Methods of utilizing native pasture in beef-cattle feeding.

Dairy cattle feeding investigations:

(1) Straw as a feed for dairy cows
(2) Straw for wintering dairy heifers
(3) Palatability and yield of various perennial pasture plants

(4) Carrying capacity of temporary pastures and response to grazing
(5) Palatability of temporary pasture crops
(6) Carotin content of pasture plants
(7) Rotation versus season-long grazing

Diseases, insects and other pests. Diseases of sorghum, alfalfa, clover and grass species.

Fort Hays Branch Experiment Station. Dryland agriculture. Forage crop investigations to test and develop improved strains, and methods of establishing or producing sweet clover, alfalfa and native grasses. Soil erosion and water conservation investigations. Bindweed control.

MAINE

Permanent pasture studies are being made. Complete fertilization is essential for the best increase during the early stages of pasture management. On "run-out" Maine permanent pastures the amount of available potash is as deficient as available phosphorus. During early stages of improvement, P and K, plus N may be added in rather large infrequent or smaller frequent applications, with about equal effectiveness. N with P and K gave the largest increases in yield. A series of grazing experiments has been started and the importance of liberal complete fertilization has been clearly shown.

A study of forty-two alfalfa strains is in progress to discover those best adapted locally. Preliminary data on hardiness and yield have been obtained. Samples from Michigan, Wisconsin and New Jersey appear to be better adapted than those from Virginia, Kansas, Nebraska, Arizona and Utah. Yield data from the first crop suggest that Ladak and Grimm are superior to most of the other strains. This alfalfa work is in co-operation with the U.S. Department of Agriculture and comprises one of the Uniform Alfalfa Nurseries.

VERMONT

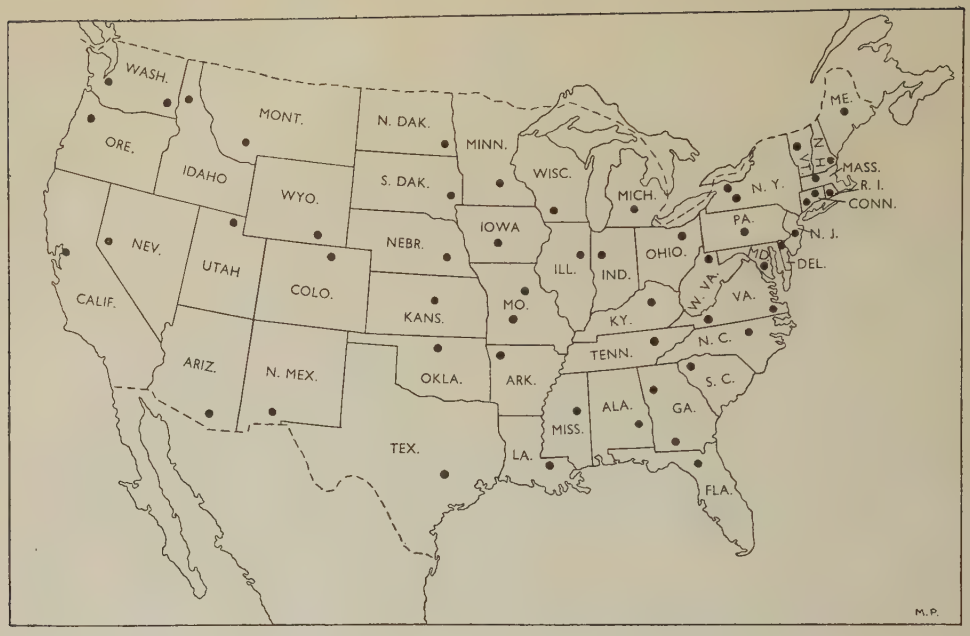
Co-operative relations have been established with the Federal Bureaux of Plant and Animal Industries with regard to pasture studies, for improving native Vermont pastures. The relative values of various seeds mixtures and of pure sowings are being studied, as well as pasture management in general. Another co-operative arrangement has been entered into between the U.S. Department of Agriculture and the North-eastern Stations from Maine to Western Virginia inclusive, in connexion with the pasture studies centred at the U.S. Regional Pasture Research Laboratory. The Agronomy Department also reports studies of floods and river-bank erosion. The Departments of Animal and Dairy Husbandry are concerned with the artificial drying of roughages (alfalfa, soybeans and timothy), the conservation of nutrients in grasses and legumes for winter feeding (alfalfa and timothy cut at two stages of maturity, ensiled with and without molasses, sun-cured and artificially dried, as were also soybeans cut at the hay stage); this study is concerned with keeping quality, digestibility of silages and hays, and feeding trials.

Map A.—Location of Agricultural Experiment Stations in their respective States (chief Centres given when there are more than one. * = not included in Map ; † = report not included in Bulletin.

Ala.	Alabama	Auburn
	*Alaska	College
Ariz.	Arizona	Tucson
Ark.	Arkansas	Fayetteville
Calif.	California	Berkeley
Colo.	Colorado	Fort Collins
Conn.	Connecticut	Storrs ; New Haven
Del.	Delaware	Newark
Fla.	Florida	Gainesville
Ga.	Georgia	Experiment
	*Hawaii	Honolulu
	Idaho	Moscow
Ill.	Illinois	Urbana
Ind.	†Indiana	La Fayette
	Iowa	Ames
Kans.	Kansas	Manhattan
Ky.	Kentucky	Lexington
La.	†Louisiana	University
Me.	Maine	Orono
Md.	Maryland	College Park
Mass.	Massachusetts	Amherst
Mich.	Michigan	East Lansing
Minn.	Minnesota	St. Paul
Miss.	†Mississippi	State College
Mo.	Missouri	Columbia
Mont.	Montana	Bozeman
Nebr.	Nebraska	Lincoln
Nev.	Nevada	Reno
N.H.	New Hampshire	Durham
N.J.	New Jersey	New Brunswick
N. Mex.	New Mexico	State College
N.Y.	New York	Ithaca
N.C.	North Carolina	Raleigh
N. Dak.	North Dakota	Fargo
	Ohio	Columbus and Wooster
Okla.	Oklahoma	Stillwater
Oreg.	Oregon	Corvallis
Pa.	Pennsylvania	State College
	†*Puerto Rico	Rio Piedras (see page 44)
R.I.	Rhode Island	Kingston
S.C.	South Carolina	Clemson
S. Dak.	South Dakota	Brookings
Tenn.	Tennessee	Knoxville
Tex.	Texas	College Station
	Utah	Logan
Vt.	Vermont	Burlington
Va.	†Virginia	Blacksburg
	†Virgin Islands	Christiansted, St. Croix (see page 44)
Wash.	Washington	Pullman
W. Va.	West Virginia	Morgantown
Wis.	Wisconsin	Madison
Wyo.	Wyoming	Laramie

Map B.—Centres mentioned in the account of research in the Division of Forage Crops and Diseases (pp. 9-18).

1. U.S. Regional Pasture Research Laboratory, Pennsylvania
2. Arlington Experiment Farm, Virginia
3. Tifton, Georgia
4. Gainesville, Florida
5. Madison, Wisconsin
6. U.S. Regional Soybean Industrial Products Laboratory, Illinois
7. Lincoln, Nebraska
8. Manhattan, Kansas
9. Woodward, Oklahoma
10. Cheyenne, Wyoming
11. Bozeman, Montana
12. Logan, Utah
13. Pullman, Washington
14. Corvallis, Oregon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CALIF.
IDAHO
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MONT.
WYO.
UTAH
ARIZ.
COLO.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KANS.
OKLA.
TEX.
MINN.
IOWA
MO.
ARK.
LA.
WISC.
ILL.
MICH.
IND.
OHIO.
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S. C.
N. C.
VA.
W. VA.
PA.
N. Y.
MD.
DEL.
N. J.
ME.
VT.
N. H.
MASS.
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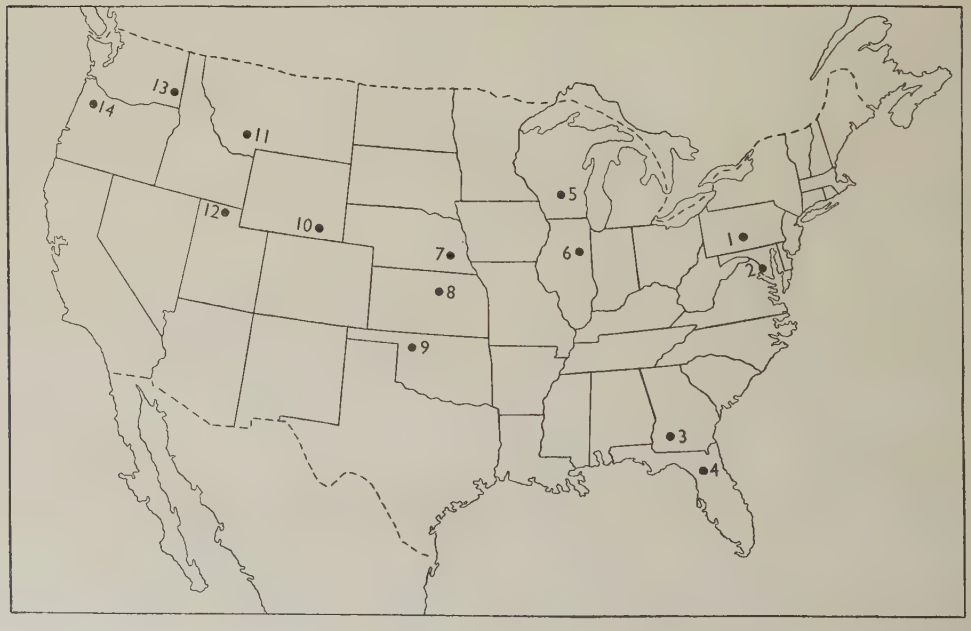
CONN.
M.P.

Map A.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Map B.

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